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Applying the risk management standard to the risk management process of a construction project

Thesis submitted in partial fulfilment of the requirements for the degree of Master of Science in Technology.

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Abstract of master's thesis

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Abstract

Business in the field of construction is risky due to many characteristics of construction projects such as the unique end-product, complicated processes, and a large number of stakeholders. Project risk management is a process in which risks that the project is facing are identified, analysed, evaluated, treated, monitored, and reviewed. The objective of risk management is to decrease consequences and likelihood of negative events and increase consequences and likelihood of positive events. There are multiple, highly similar theories for risk management. This thesis uses a process by ISO 31000:2018 as its framework.

The objective of this thesis is to study how the risk management standard can be applied to the risk management process of a construction project. This objective is strived to achieve by answering research questions, which compare the risk management guidelines of a construction company, and risk management operations in projects to the risk management standard. The research is divided into two sections: the first section is a literature review, and the second is an empirical study.

Empirical research is conducted through a case study of a construction company. The case company approach is selected because it allows the research of project risk management guidelines of a construction company and an in-depth study of actual risk management operations in projects. Empirical research consists of three data collection methods: a documentary study, interviews, and a questionnaire. The documentary study is made in order to gather data about the risk management guidelines of the case company. Interviews, with 25 interviewees and the questionnaire, with 107 respondents were conducted to collect data about the risk management operations and course of risk management actions in projects.

This thesis provides a comprehensive and detailed description of risk management in construction projects. As a result of the study is stated that the standard can be applied in construction project risk management. However, the risk management process by ISO may seem complicated and theoretical, and thus, it is essential to customise the process to be suitable for the company and the project in question. In this study was found that course of risk management actions varies a lot between projects. Furthermore, the importance of suitable resources, guidelines and risk management training and communication is highlighted in order to make the risk management effective.

Keywords Risk management, risk management process, ISO 31000, construction project

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Diplomityön tiivistelmä

Tekijä Anni Kankare		
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Tiivistelmä

Liiketoiminta rakennusalalla on riskialtista rakennusprojekteille erityisten piirteiden, kuten ainutlaatuisen lopputuotteen, monimutkaisten prosessien ja suuren sidosryhmien määrän vuoksi. Projektiriskienhallinta on prosessi, jossa projektiin kohdistuvat riskit tunnistetaan, analysoidaan, arvioidaan, käsitellään, seurataan ja katselmoidaan. Riskienhallinnan tavoitteena on vähentää negatiivisten tapahtumien seurauksia ja todennäköisyyttä sekä lisätä positiivisten tapahtumien seurauksia ja todennäköisyyttä. Riskienhallintaan on olemassa useita, hyvin samankaltaisia teorioita. Tämän tutkielman viitekehyksenä käytetään ISO 31000:2018 -standardin mukaista riskienhallintaprosessia.

Tämän tutkielman tavoitteena on tutkia, miten riskienhallintastandardia voidaan soveltaa rakennusprojektin riskienhallintaprosessiin. Tämä tavoite pyritään saavuttamaan vastaamalla tutkimuskysymyksiin, jotka vertailevat rakennusyrityksen riskienhallinnan ohjeistusta ja projektien riskienhallintatoimia ISO:n riskienhallintastandardiin. Tutkimus on jaettu kahteen osaan: ensimmäinen osa on kirjallisuuskatsaus riskienhallinnasta ja toinen on empiirinen tutkimus.

Empiirinen tutkimus suoritetaan tapaustutkimuksena rakennusliikkeestä. Tutkimusmenetelmäksi on valittu case-yrityksen tarkastelu, koska se mahdollistaa rakennusliikkeen projektiriskienhallinnan ohjeistuksen ja riskienhallintatoimien syvällisen tutkimisen. Empiirinen tutkimus koostuu kolmesta datan keruumenetelmästä: dokumenttitutkimuksesta, haastatteluista ja kyselytutkimuksesta. Dokumenttitutkimus tehdään, jotta saadaan kerättyä tutkimusaineistoa case-yrityksen riskienhallinnan ohjeistuksesta. Haastattelut, jossa oli 24 haastateltavaa, ja kysely, johon vastasi 107 henkilöä laaditaan, jotta saadaan kerättyä tutkimusaineistoa riskienhallintatoimista projekteissa.

Tämä tutkimus tarjoaa kattavan ja yksityiskohtaisen kuvauksen rakennusprojektien riskienhallinnasta. Tutkimuksessa esitetään, että riskienhallintastandardia voidaan soveltaa rakennusprojektien riskienhallintaan. ISO:n määrittelemä riskienhallinta prosessi saattaa vaikuttaa monimutkaiselta ja vaikuttaa tarpeettoman teoreettiselta, joten olennaista on muokata prosessi yritykselle ja projektille sopivaksi. Tutkimuksessa paljastui, että riskienhallinnan toimintatavat vaihtelevat paljon projektien välillä. Lisäksi, vaikuttavan riskienhallinnan saavuttamiseksi korostui sopivien resurssien, yhtenäisten toimintaohjeiden ja riskienhallintakoulutuksen tärkeys.

Avainsanat Riskienhallinta, riskienhallintaprosessi, ISO 31000, rakennusprojekti

Preface

The starting point for my thesis was that I wanted it to be useful for my employer, NCC Suomi Oy. I felt that no topic was of the utmost interest. Furthermore, I found out that I was most motivated by the usefulness of the work, both for my employer and for science in general. With this in mind, I started to map the subject of the thesis, and I would like to thank Tuomas Tonteri, operations manager of our department, Residential Construction Helsinki, for introducing me to a fascinating topic; risk management of construction projects.

Quickly, the work expanded to concern the entire NCC Building Finland business area instead of one department. Markus Suomi, Quality and Sustainability Manager, Building Nordics / Sustainability Manager, Building Finland and Ilkka Forsell, Head of Risk Management NCC Building Finland promised to be my thesis' advisors. I am glad and grateful that I got this exciting and important topic as the subject of my master's thesis. I believe this topic has given me the enormous potential for the future, not just in my work career but in all aspects of my life. Is it not that life is constant risk management?

I would like to thank my thesis' advisors Markus Suomi and Ilkka Forsell for encouraging and trusting me. It has been a pleasure working with you. Also, big thanks belong to my supervisor, assistant professor Antti Peltokorpi. Furthermore, I would like to thank a large crowd of over a hundred people who contributed to my work by participating to the empirical study. It has been great to notice how helpful and enthusiastic people I am enabled to work with.

However, the biggest thanks go to my dear neighbour, best friend, and sister Suvi. She did her masters' thesis at the same time as me, and actually, our writing sessions in the evenings have been surprisingly effective. There is no one else I would rather celebrate my graduation with. Thank you!

Finally, I want to thank my friends and family for supporting me throughout my studies. It is great that my life has been blessed with so many truly wonderful people.

"The biggest risk is not taking any risk. In a world that's changing really quickly, the only strategy that is guaranteed to fail is not taking risks."
– Mark Zuckerberg

Espoo 27.4.2020

Anni Kankare

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1 Introduction

1.1 Background

Construction projects are complex and unique in terms of their size, location, project organisation, timeframe, and planning. There are multiple stakeholders with various interests involved. (Raj & Wadsamudrakar, 2018.) The construction projects require interpretation of and compliance with many laws, codes, and regulations, and they have time, cost, and quality targets to meet (Chartered Institute of Building, 2019, pp. 10-13). Thus, there are significant risks involved in construction projects when compared to many other manufacturing industries. The construction industry is subject to more risks because of the unique features of construction activities such as complicated processes, long planning and construction periods, dynamic organisations, financial intensity, and challenging environment. (Zou et al., 2006.)

Risk is an uncertain condition or event that, if realised, has a negative or positive effect on the objective of the organisation or project (Project Management Institute, 2017, p. 397). Risk is generally described as the combination of the likelihood of an event and its consequences (ISO/TR 31004:fi, 2014, p. 21). The key threats that influence construction project objectives are tight project schedules, design variations, excessive approval procedures in administrative government departments, and high performance or quality expectations (Zou et al., 2006). These risks are intensively managed through various risk management methods and techniques.

Risk management is a process in which risks that the organisation or project is facing are identified, analysed, evaluated, treated, monitored, and reviewed. The objective of risk management is to decrease the likelihood and consequences of negative events and increase the likelihood and consequences of positive events in the project. (Project Management Institute, 2013, p. 319.) While risk management cannot eliminate risk, it can be used to reduce the impact of events that may prevent the achievement of project goals (Morledge & Adrian, 2013, p. 182).

It has been argued that there is a direct relationship between effective risk management and project success since risks are assessed by their potential effect on the objectives of the project (Baloi & Price, 2003). In construction projects, risk management has been recognised as an essential management process in order to achieve the project objectives in terms of cost, time, safety, quality, and environmental sustainability (Zou et al., 2006). Thus, risk management is a significant feature of the management of construction projects (Raj & Wadsamudrakar, 2018).

Figure 1 demonstrates the potential that can be achieved in construction projects through risk management. The red line represents a project with a lower degree of risk management and green with a higher degree. Blue arrows describe the benefits achieved by the addition of risk management. These benefits are increasing the quality of planning, cost of realisation, reduction of processing time, and acceptance. (Schieg, 2003.)

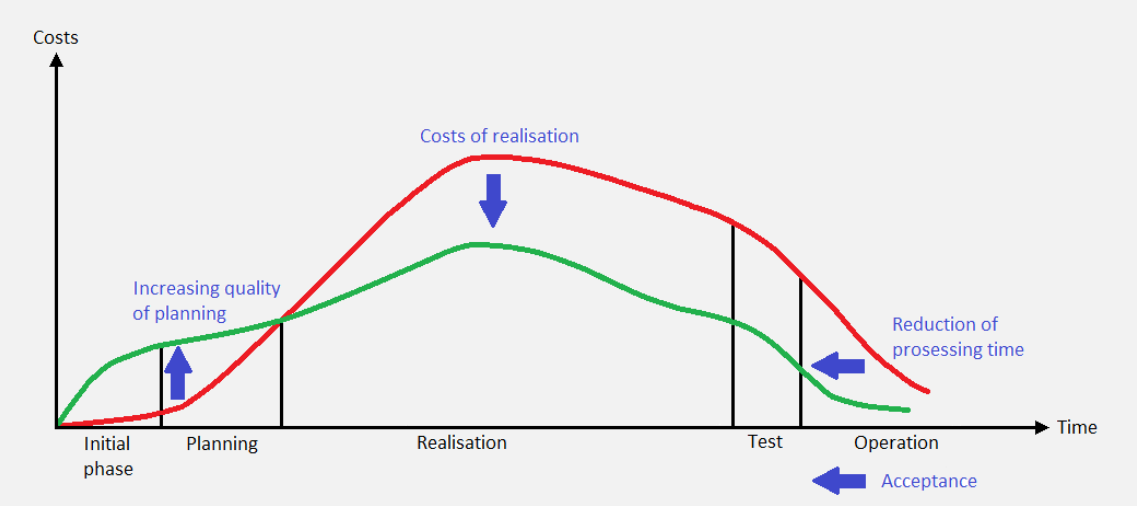

Figure 1. Potential achieved by risk management in construction projects (edited, Schieg, 2003).

There are multiple, highly similar theories for risk management. Some of the theories limit their scope of application to risk management in projects while the other can also be used in organisational risk management. However, according to Raz & Hillson (2005), there are no significant differences in the structure of the processes, although the scope of the application varies. Thus, there is a broad consensus regarding the main stages and activities of the risk management process of these theories. (Raz & Hillson, 2005.) Nieto-Morote & Ruz-Vila (2011) have studied that the components of the process that are repeated in different theories are risk identification, risk assessment, risk response, and risk monitoring and reviewing.

This thesis uses the risk management process of the standard ISO 31000:2018 as its framework. International Standardization Organization ISO is an independent, non-governmental international organisation for proprietary, industrial, and commercial standard developing. ISO is composed of recognised authorities on standards. Each of these members represents one country, and in total, ISO has 164 members. The representative of Finland is the Finnish Standards Association SFS. (International Standardization Organization ISO, 2020.)

The decision to use the process by ISO 31000:2018 is made based on the broad scope of the process. Unlike some of the processes, ISO 31000:2018 takes into account the monitoring and review of the process itself. The critical evaluation of the risk management process itself enables its continuous improvement. Also, unlike some of the theories, ISO 31000:2018 process considers both positive and negative risks. The standard ISO 31000:2018 has been formally adopted by many countries to replace their national standards (Purdy, 2010). In Finland, the standard ISO 31000:2018 has the status of a Finnish national standard (SFS-ISO 31000:2018, 2018, p. 1).

The standard ISO 31000:2018 defines guidelines for risk management. These include the process itself, then framework, within the process should be implemented, and finally, principles that should be fulfilled in order to make risk management effective. Guidelines can be entirely or partly adapted and improved to make risk management efficient, effective, and consistent. The standard sets out a general approach to managing all types of risk, which can be utilised in all industries. (SFS-ISO 31000:2018, 2018, pp. 5-6.) Although ISO

31000:2018 is a standard, it is not made for certification purposes. However, it provides guidance for external or internal audit programmes. (International Standardization Organization ISO, 2020.)

There has been somewhat research about risk management in the construction industry. However, there are only a few studies about the use and application of merely ISO 31000 process in construction project risk management. Thao et al. (2014) researched risk management in construction projects based on ISO 31000, but in developing countries. Rahimi et al. (2018). studied a hybrid approach for risk management based on failure mode effects analysis (FMEA) and ISO 31000 guidelines in construction projects. Pillay & Jefferies (2015) did research about risk management of construction health and safety based on ISO 31000 process. In other areas, there are studies about the use of ISO 31000 process, for example, in road safety (Marin, 2017) and tailings dam safety (Cruz & Rodovalho, 2019). Also, the use of ISO 31000 has been studied for example in IT-organisations (Barafort et al., 2018), banking companies (Duţă, 2016), and private security companies in South Africa (Govender, 2019).

1.2 Research objectives

The objective of this thesis is to study how the risk management standard can be applied to the risk management process of a construction project. This objective is strived to achieve by answering research questions, which are:

RQ 1 How well is the project risk management process defined by a construction company in line with the risk management process by ISO 31000:2018?

RQ 2 How well risk management operations in projects follow the project risk management process defined by a construction company?

RQ 3 How the risk management operations in the projects correspond to the ISO 31000:2018 standard?

These main research questions are supported by subquestions, which make it possible to answer the main research questions. Subquestions for the research questions are as follows:

RSQ 1 What is the risk management process defined by ISO 31000:2018?

RSQ 2 What is the project risk management process defined by a construction company?

RSQ 3 How is risk management implemented in practice in projects?

This thesis is a descriptive research. Thus, it aims to give a detailed depiction of the risk management process defined by a construction company and how the risk management process is implemented in the project level. Such depictions have not done much, at least specifically from the perspective of a construction project. The practical objective of the thesis is to improve the project risk management process of the case company that ordered this study.

1.3 Research scope

The risk management process defined by ISO may be applied at different levels in the organisation. However, this research is limited to the project level. Therefore, this study does not stand on risk management concerning, for example, strategic, operational, and program level. The delimitation is done so that the thesis can focus only on project risk management.

In construction projects, there are also many different levels of risk management. For example, supervisors perform risk management in their daily work when they plan their upcoming tasks or do safety checks. However, this thesis focuses on a regular, project-wide risk assessment that is recorded to the risk register.

There are no restrictions on project delivery methods in order to keep the thesis at a general level. When using this research as a source of information, it should be taken into account that different project delivery methods may require specific considerations in risk management.

The topic is limited to building business. It means that this thesis does not deal with construction in the field of, for example, infrastructure or industry. In this thesis, building business includes the construction of housing, offices, public and commercial premises, both new construction and renovation. With this delimitation, the subject area does not expand to the area where risks vary considerably. The research is done from the contractor's point of view. Furthermore, it focuses only on contracting, not on developer-contracting. These delimitations are done in order to keep the scope limited.

The focus of the research is in the tender and construction phase. The warranty phase is considered only from the exchange of the information point of view. In the warranty phase, many factors, such as possible risks, stakeholders, managers, and owner of the building, are different compared to the tender and construction phase. Thus, the warranty phase is scoped outside of the research.

The ISO 31000:2018 risk management standard defines guidelines that include process, framework, and principles. However, the focus of this thesis is in the process in order that the topic of the thesis does not expand overly broad.

1.4 Research methods

In this thesis, the risk management process is separated into three levels, which are presented in Figure 2.

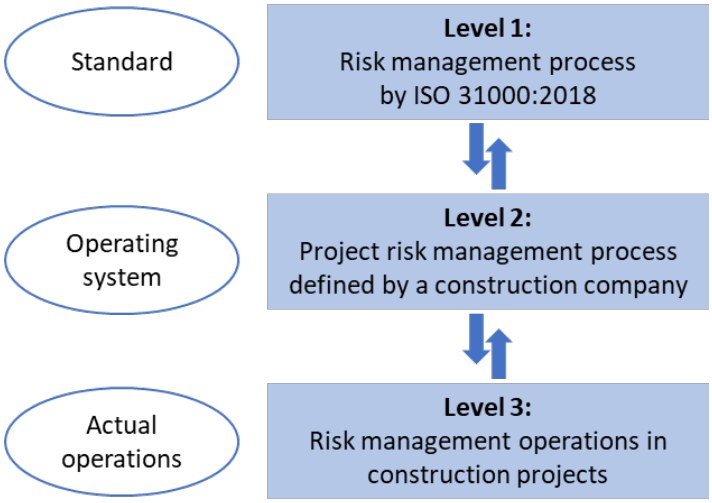

Figure 2. Three risk management levels used in this thesis.

In the next page, Figure 3 represents the entire structure of the research. Level one is the risk management process defined by ISO, and it is researched through research subquestion RSQ 1. Level two is a project risk management process defined by a construction company, and it is researched with research subquestion RSQ 2. Level one is used as a frame of reference, which is compared to the risk management process defined by a construction company. Thus, the first main research question is considering the relation between levels one and two.

However, we cannot directly assume that practical, actual risk management operations and practices in projects are following the guidelines of the company. Level 3 signifies the actual operations made in projects, and it is researched with subquestion SRQ 3. The second research question is dealing with the relation between level 2 and level 3.

Finally, research question three is dealing with the relation between levels one and three. The aim of the research question three is to find how the risk management operations in the projects correspond to the guidelines defined in the standard ISO 31000:2018.

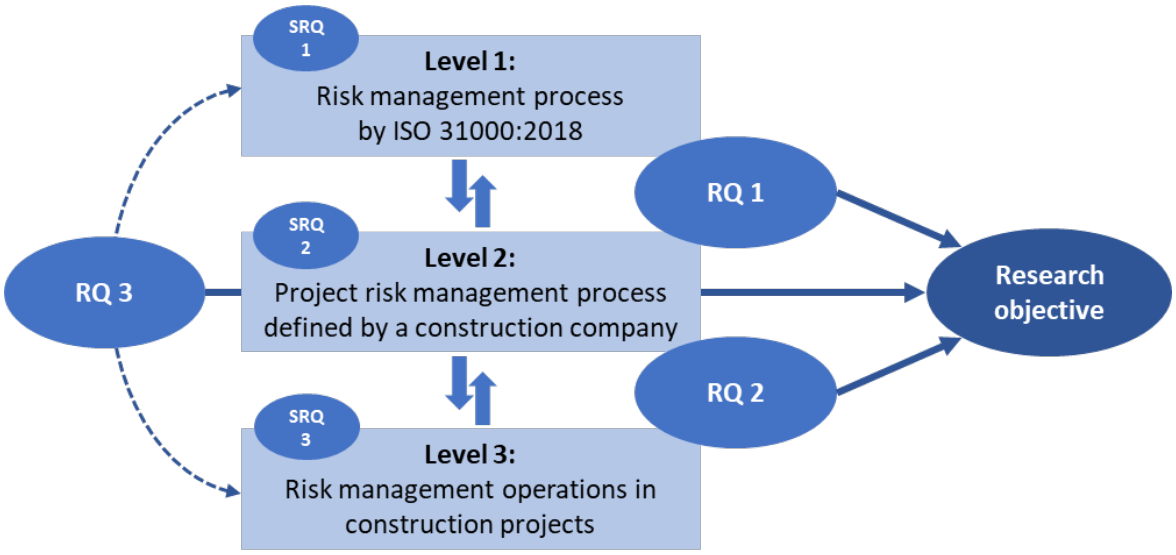

Figure 3. The structure of the research.

This thesis is conducted via a literature review and empirical study. Information for level one, and answer to research subquestion RSQ 1, has been obtained through the literature review. The primary resource for the literature review is SFS-ISO 31000:2018 'Risk Management – Guidelines' standard by the International Standardization Organization ISO. Technical report ISO/TR 31004:2014 'Risk management. Guidance for the implementation of ISO 31000' and standard SFS-EN IEC 31010:2019 'Risk management – Risk assessment techniques' was used to support the interpretation of the SFS-ISO 31000 standard. These documents are not contradictory but made to support each other. These three documents were obtained through the SFS, Finnish Standards Association.

Other academic articles related to construction projects and risk management were searched mostly via Google Scholar. Through Google Scholar, access to 'Elsevier', 'ScienceDirect', and 'Taylor & Francis Online' was obtained. These search engines offer numerous suitable documents for an academic reference. References included academic articles from journals, such as 'International Journal of Project Management', 'Journal of Business Economics and Management', and 'Journal of Operations Management'.

The empirical research is conducted through a case study of a construction company. According to Hirsjärvi et al. (2009, pp. 134-135), the case study approach is a commonly used method when processes are studied. Also, the case study approach is selected to be the data collection method of this research because it is a suitable method when the purpose is to collect highly detailed data. (Hirsjärvi et al., 2009, pp. 134-135). Furthermore, the case company approach allows the study of project risk management guidelines of an existing construction company. Also, an in-depth study of actual risk management operations in construction projects is possible with case company approach.

The case company for this thesis is NCC Suomi Oy and based on the scope of the thesis, respondents for interviews and a questionnaire are part of the NCC Building Finland business area. NCC Suomi Oy is suitable for the case company of this study because its risk management process is created based on the ISO 31000 guidelines. Empirical research consists of three data collection methods: a documentary study, interviews, and a questionnaire. These methods are used to gather data for levels two and three.

The data for level two, and to the answer of research subquestion RSQ 2 is collected mainly from the risk management documents achieved from the company's internal operating system (toimintajärjestelmä). Interviews and a questionnaire were selected to be the methods to collect data about actual risk management operations done in construction projects. Interviews and a questionnaire were done in order to gather information mainly to level three. They strive to answer to the research subquestion RSQ 3.

Interviews allow obtaining in-depth information and opinions from individuals. Interviewees were selected subjectively, and thus, interviews are used mostly to gather qualitative data. However, a questionnaire was conducted in order to gather quantitative data to support qualitative data from interviews. A questionnaire is a suitable method for quantitative data collection because broader, and the more objective audience is reached. Also, the outputs of the questionnaire are easy and fast to handle numerically. The data from interviews and the questionnaire are handled anonymously in order to encourage respondents to answer as truthfully as possible.

The thesis is divided into six chapters. After this introduction, the second chapter includes the literary review of project risk management. The second chapter is divided into nine subchapters, of which subchapter 2.1 deals with the concept of risk and subchapter 2.2 with risk management theories. Subchapter 2.3 gives a compact introduction to risk management techniques. Subchapter 2.4 concerns the risk management process defined by the standard ISO 31000:2018. Subchapters 2.5 and 2.6 focus on risk assessment and treatment. Then, subchapter 2.7 introduces the risk management framework within the process should be implemented, and subchapter 2.8 deals with the principles that should be fulfilled in order to make risk management effective. Finally, subchapter 2.9 focuses on risk management specifically from the construction project point of view.

The third chapter includes the empirical study of this thesis. Subchapter 3.1 concerns the methodology for the empirical study. Then, the rest of the subchapters are divided based on the data collection method so that subchapter 3.2 concerns data achieved from the documentary study, and 3.3 the results from interviews and the questionnaire. In chapter four, the results for the main research questions are introduced. Finally, chapter five includes discussion and conclusion. Results from chapter four are generalised, recommendations for the improvement of the project risk management are presented, reliability and validity of the research concerned, and suggestions for further research made. The body of interviews and the body of the questionnaire are at the end of the thesis as appendixes.

2 Literature review

2.1 Risk

International Standards Organization ISO (2018, p. 25) defines risk as *"an effect of uncertainty on objectives"*. The effect is defined as a deviation from the expected. The effect can be negative, positive, or both, and it can create or result in threats and opportunities. (SFS-ISO 31000:2018, 2018, p. 25.) Objectives have different aspects, such as financial, safety, and environmental goals, and can apply at different levels, such as strategic, organisation-wide, project, process, and product-level (SFS-OPAS 73, 2011, p. 8).

All organisations and projects are subject to risk. They face uncertainties, internal and external factors and influences that make it uncertain whether they will achieve their objectives on schedule and to what extent. (ISO/TR 31004:fi, 2014, p. 20.) The realisation of the risks is entirely random, but based on historical data, it is possible to estimate the probabilities of the risk realisation (Suominen, 1999, p. 10).

Because of the definition of the term 'risk', a source of risk should not be called as a risk (ISO/TR 31004:fi, 2014, p. 20). However, risk should be expressed in addition to risk sources, also in terms of potential events, their consequences, and their likelihood. The risk source is an element that, alone or in combination, has the potential to give rise to risk. An event can be defined as an occurrence or change of a set of circumstances. Therefore, an event can be a source of risk. (SFS-ISO 31000:2018, 2018, pp. 6-7.) Often, the risk is described as the combination of the likelihood of a source of risk and its consequence (ISO/TR 31004:fi, 2014, p. 21). Likelihood means the chance of something happening and consequence means the outcome of an event affecting objectives. Both likelihood and consequences can be expressed qualitatively or quantitatively. (SFS-ISO 31000:2018, 2018, p. 7.)

The mathematical definition of risk can be defined as:

risk = likelihood (x) consequence of the risk,

where the likelihood is expressed as a percentage, and the consequence is often measured as costs (Suominen, 1999, p. 10).

When dealing with risks, the literature sometimes uses the term 'uncertainty' to describe risk. However, distinguish between events that are 'risky' and events that are 'uncertain' is essential. (Morledge & Adrian, 2013, p. 183.) According to SFS-OPAS 73 (2011, p. 8), uncertainty is *"the state, even partial, of deficiency of information related to, understanding or knowledge of, an event, its consequence, or likelihood."* Hillson (2004, p. 6) captured the link of risk and uncertainty with the following couplet: *"Risk is measurable uncertainty; Uncertainty is unmeasurable risk."* Morledge & Adrian (2013, p. 183) explain that risky events can be predicted at least some degree, and uncertain events are random events that cannot be predicted. Thus, risk events can be managed, and uncertain events cannot. The only way to manage uncertain events is to reduce them to the minimum. The reduction can be made by converting them into events that can be predicted, for example, by gathering more information about the event. (Morledge & Adrian, 2013, p. 183.)

The traditional view of risk is negative, and thus, the common usage of the word 'risk' sees only the downside (Hillson, 2002). Lehtiranta (2014) researched the perception of risk in

professional literature published between 2000 and 2012. Among 66 construction project -related references, 88 % considered risk as a negative risk, and only 12 % considered risk as a negative or a positive risk. (Lehtiranta, 2015.) However, nowadays there are several risk management theories and standards, such as the ISO standard used as the reference framework for the thesis, that defines risk to be a negative or positive effect on project objectives. This integrated approach sees that with the same risk management process, negative risks can be minimised, and positive risks maximised at the same time. (Hillson, 2002.)

Due to this background, most of the literature uses the term 'risk' to describe negative risk and 'opportunity' to describe positive risk. However, according to ISO, negative risk should be appointed as 'a threat' and positive risk as 'an opportunity'. This thesis will use the latter definition. Thus, when the word 'risk' is used, it includes both negative and positive aspects.

Also, although 'source of risk' should not be called as 'risk', almost all the literature and also spoken language use the term 'risk'. This thesis will also use the term 'risk' instead of the term 'risk source'.

2.2 Risk management theories

According to SFS-ISO 31000:2018 (2018, p. 14), risk management process involves *"the systematic application of policies, procedures and practices to the activities of communicating and consulting, establishing the context and assessing, treating, monitoring, reviewing, recording and reporting risk."* The theoretical purpose of risk management is value creation and protection. This objective is achieved by controlling the effects of uncertainty. (SFS-ISO 31000:2018, 2018, p. 7.) In practice, the objective of risk management is to decrease the likelihood and consequences of negative events and increase the likelihood and consequences of positive events in the project. (Project Management Institute, 2013, p. 319.) Effective risk management supports the achievement of objectives, improves performance, and encourages innovation (SFS-ISO 31000:2018, 2018, p. 7).

According to Morledge & Adrian (2013), risk management cannot eliminate threats. However, effective risk management can reduce the impact of events that may cause failure to reach the desired objectives. (Morledge & Adrian, 2013, p. 182.)

The risk management process by ISO is illustrated in Figure 4. The same process is used for both, to ensure that unwelcome, negative effect of uncertainty is minimised and beneficial uncertainty that can result in opportunities is maximised.

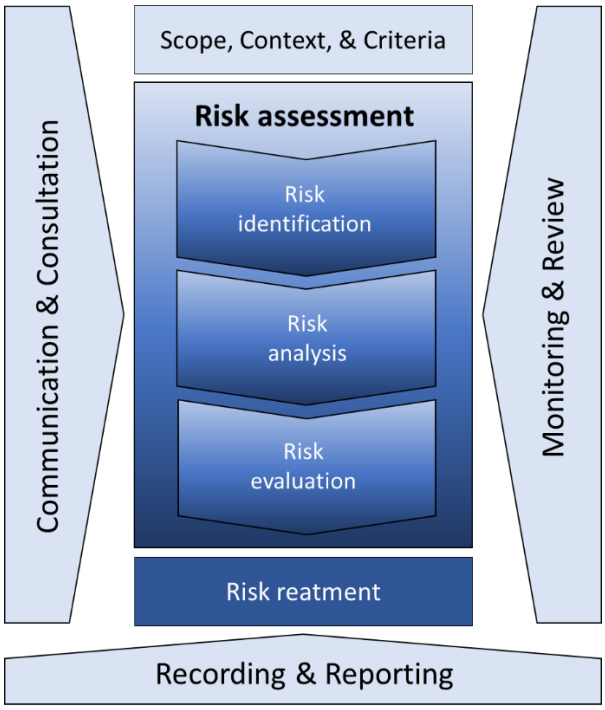

Figure 4. The risk management process by the International Standards Organization ISO (edited, SFS-ISO 31000:2018, 2018, p. 32).

In addition to the risk management process established by ISO, there are several risk management theories or approaches developed by various people or organisations such as Project Risk Analysis and Management (PRAM) by Association for Project Management (1st edition published in 1997), Risk Analysis and Management for Projects (RAMP) by Institution of Civil Engineering and The Actuaries Profession (1st edition published in 1998), and A Guide to the Project Management Body of Knowledge (PMBOK) by Project Management Institute (1st edition published in 1998). Figure 5 demonstrates the main features of these processes.

However, as can be seen from Figure 5 and also according to Nieto-Morote & Ruz-Vila (2011), most of the risk management theories involve a similar framework and following four stages, which are:

(1) Risk identification, which means the process of determining and documenting risks that may affect the objectives of the project.
(2) Risk assessment, which means the process of prioritising risks.
(3) Risk response, which means the process of developing options and actions to reduce threats and to enhance the opportunities of the project.
(4) Risk monitoring and reviewing, which means the process of implementing a risk treatment plan, tracking identified risks, monitoring residual risks and identifying new risks. It also contains an evaluation of the effectiveness of the risk management process.

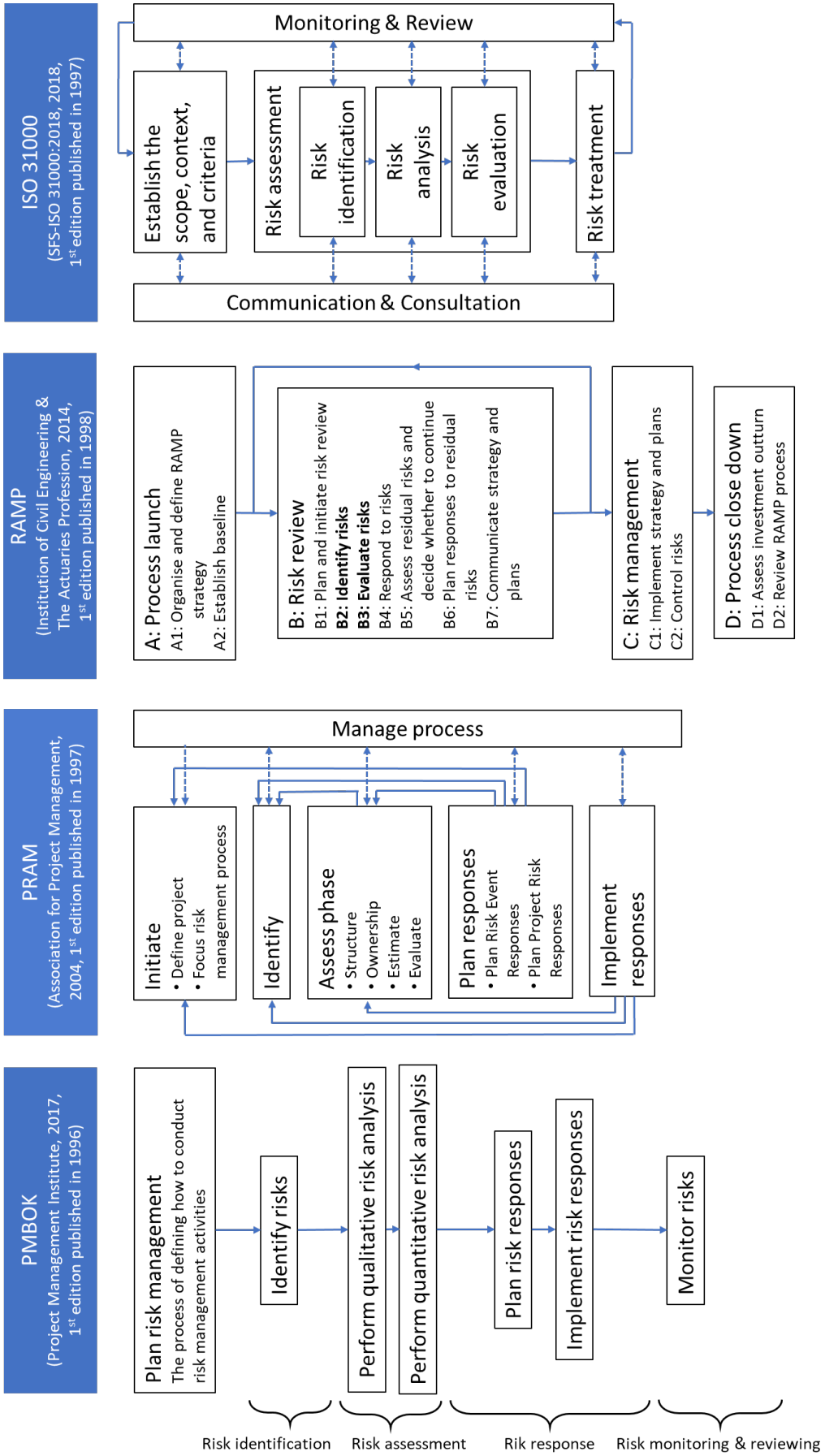

Figure 5. Comparison of risk management processes.

Raz & Hillson (2005) concluded that apparent differences in theories are mostly attributable to variations in terminology. However, there is also genuine and material differences among risk management theories that arise from three sources. The first source is the inclusion of additional elements or components beyond the central risk management process, such as communication, consultation, and collaboration with stakeholders, links to the objectives and strategy of the organisation, and guidance for implementation of risk management activities in the organisation. The second difference is related to the scope of the theory's coverage. Some theories, such as PMBOK (Project Management Institute, 2017), covers only the risk management process itself. Whereas theories, such as standard ISO 31000:2018, also focus on monitoring and review of the process. Monitoring and review of the process include, for example, examine the effectiveness of the process, generating lessons learned, and improving the process continuously. The third difference in these risk management theories is the definition of 'risk'. Some theories (such as ISO 31000:2018), defines 'risk' to include both, possible positive and possible negative impact, while some (for example IEEE Std 1540-2001, 2001) focus only to the negative risks. (Raz & Hillson, 2005.)

Most risk management theories emphasise that the risk management process should be applied in all phases in the life cycle of a project (Chapman, 1997). In construction, these phases are typically needs assessment, project plan, design proposal, general plan, execution plan, construction, and warranty period (RT 10-11224, 2016). It is essential to implement the risk management process from the early stages of the project since significant decisions such as the choice of alignment and construction methods can be influenced (Eskesen et al., 2004). Figure 6 represents how the level of risk and cost of change vary in the project time (Project Management Institute, 2013, p. 40). According to Thomson & Perry (1992), the most significant uncertainty is at the beginning of the project. Also, decisions with the greatest impact are made in the early phases of a construction project. (Thompson & Perry, 1992.) Risks, which have significant cost impacts, are typically identified in early phases of the construction project, and risks with more significant schedule delays are identified towards the end of the project (Anthony et al., 2015).

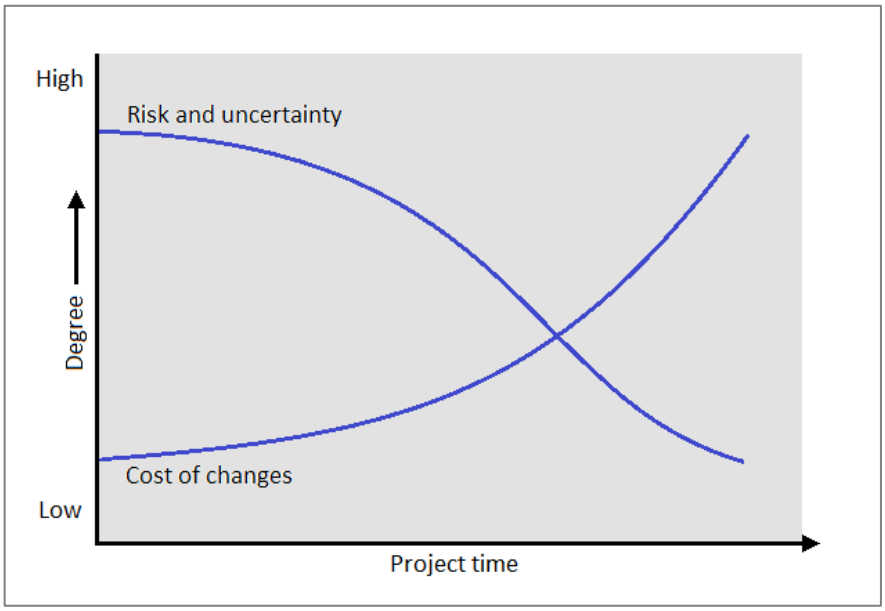

Figure 6. The impact of the variable based on project time (edited, Project Management Institute, 2013, p. 40).

The risk management process is iterative (SFS-ISO 31000:2018, 2018, p. 33). Therefore, new risks may become known as the project progresses and risks that are previously identified may drop out. Also, some of the risks require attention throughout the project, which makes continuous risk management essential. (Banaitiene & Banaitis, 2012, p. 433.)

Risk management can be seen to impact on many facets of projects. According to Burtonshaw-Gunn (2009, p. 8), a traditional point of view is that risk management is a part of the project management function. However, an alternative view is that if there were no risks in a project, there would not be a need for project management and that the primary purpose of project management is to manage the risks. From this point of view, risk management should consider all aspects of the project as presented in Figure 7. (Burtonshaw-Gunn, 2009, p. 8.)

Figure 7. Aspects of project risk management (edited, Burtonshaw-Gunn, 2009, p. 8).

Next subchapter will introduce risk management techniques which can be used throughout the risk management process.

2.3 Risk management techniques

Risk management techniques can be used to increase the understanding of uncertainty and risks that the project is facing. They also create input to decisions related to risks, such as whether and how to treat risks. Risk management techniques can be used to identify risk, determine causes, sources and drivers of risk, and understand consequences and likelihood of risk. They are also useful when analysing interactions and dependencies, reconciling a measure of risk, and exploring the effectiveness of proposed risk treatments. (SFS-EN IEC 31010:2019, 2019, pp. 18-19.)

Risk management techniques can be divided into preventive techniques and remedial techniques. Preventive techniques can be used to manage risks that are anticipated during the project execution before the start of a project. Remedial techniques can be used during the later phases of the project once a risk has already occurred. (Iqbal et al., 2015.)

The choice of suitable technique and the way it is applied is made based on the context and the use. There are numerous factors that an organisation should take into account when selecting a technique or techniques. Firstly, the purpose of the assessment and the operating environment must be considered. The needs of stakeholders, which means the kind of data stakeholders want as output, also affect the decision of a suitable technique. An organisation should make sure if any legal, regulatory, or contractual requirements could restrict the selection. The choice of technique also depends on the importance of the decision, which means, for example, the consequences if a wrong decision is made. One crucial factor is the time available before a decision must be made. Lastly, the choice should be made base on the available information and expertise. (SFS-EN IEC 31010:2019, 2019, p. 29.)

The standard SFS-EN IEC 31010:2019 provides descriptions of a comprehensive set of methods that can be used through the risk management process. Figure 8 in the next page demonstrates in which stages of a risk management process commonly used risk management techniques can be used.

The risk management process by the International Standards Organization ISO is divided into components which were presented earlier in Figure 4. Next subchapter will concern these components, and some of the most used risk management techniques are described.

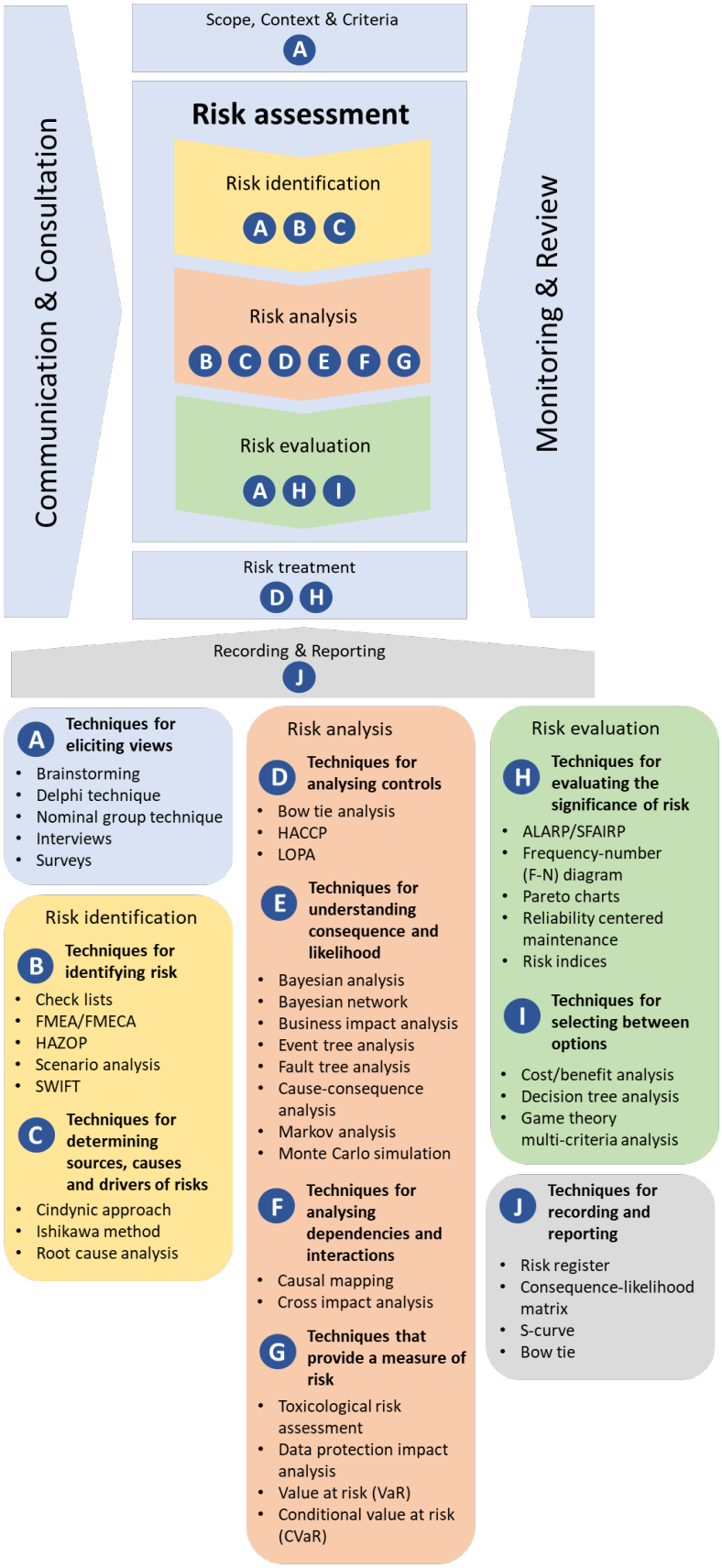

Figure 8. Application of risk assessment techniques in the ISO 31000 risk management process. Note that figure provides an overview of techniques, and it is not an exhaustive list of risk management techniques. (Edited, IEC 31010:2019, 2019, p. 37.)

2.4 Risk management process by ISO 31000:2018

Scope, context, and criteria

At the beginning of the risk management process, the scope, context, and criteria of the process should be defined. The purpose of defining these factors is to customise the risk management process so that it is suitable and effective for the organisation or project in question. (SFS-ISO 31000:2018, 2018, p. 15.)

The risk management process may be applied at different levels, such as strategic, operational, program, or project level (SFS-ISO 31000:2018, 2018, p. 15). Therefore, the **scope** of the process should be defined. This thesis considers risk management only at the project level. The standard SFS-ISO 31000:2018 (2018, p. 15) defines the following considerations about the scope of the process made when planning the approach (directly quoted):

- *"objectives and decisions that need to be made*
- *outcomes expected from the steps to be taken in the process*
- *time, location, specific inclusions and exclusions*
- *appropriate risk assessment tools and techniques*
- *resources required, responsibilities and records to be kept*
- *relationships with other projects, processes, and activities."*

The definition for internal and external **context** by SFS-ISO 31000:2018 (2018, p. 15) is *"the environment in which the organisation seeks to define and achieve its objectives."* The features of the context should be established based on the internal and external environment in which the project is operated. (SFS-ISO 31000:2018, 2018, p. 15.)

According to the standard SFS-ISO 31000:2018 (2018, p. 15), understanding the context is essential because risk management takes place in the context of the activities and objectives of the organisation. The context is crucial also because organisational factors can be a source of risk. When an organisation is establishing the internal and external context of the project risk management process, it should consider the factors listed in Table 1. (SFS-ISO 31000:2018, 2018, p. 15.)

Table 1. Factors to be considered when defining the context of the risk management process (compiled from SFS-ISO 31000:2018, 2018, p. 11).

External context
The social, cultural, political, legal, regulatory, financial, technological, economic, and environmental factors (whether international, national, regional, or local)
Key drivers and trends affecting the objectives of the organisation
External stakeholders' relationships, perceptions, values, needs, and expectations
The complexity of networks and dependencies
Internal context
Vision, mission, and values
Governance, organisational structure, roles, and accountabilities
Strategy, objectives, and policies
Organisation's culture
Standards, guidelines, and models adopted by the organisation
Capabilities understood in terms of resources and knowledge (e.g., capital, time, people, intellectual property, processes, systems, and technologies)
Data, information systems, and information flows
Relationships with internal stakeholders, taking into account their perceptions and values
Contractual relationships and commitments
Interdependencies and interconnections

At the beginning of the risk management process, and the latest before risk assessment, the organisation should specify and establish **risk criteria** for the project. There are many types of risk criteria. The first risk criteria are the amount and type of risk that can be accepted. The second is criteria for evaluating the significance of risk and the third is criteria that assist in deciding between options to support decision-making. Risk criteria can be qualitative, semi-quantitative or quantitative. (SFS-EN IEC 31010:2019, 2019, p. 14.) In addition to that risk criteria should be established at an early phase of the risk management process, risk criteria should be reviewed and modified continuously throughout the process. (SFS-ISO 31000:2018, 2018, p. 16.)

When an organisation is defining its risk criteria, it should consider multiple aspects. Firstly, it should find what is the nature of possible risks and how consequences and likelihoods are defined and measured. It should also decide how the level of risk is to be determined. It is also essential to take care that there is consistency in the use of different measurements. An organisation should consider how they will take into account the combinations and sequences of multiple risks. Lastly, when an organisation is defining its risk criteria, it should consider the capacity of the organisation. (SFS-ISO 31000:2018, 2018, p. 16.)

Risk criteria should reflect the organisation's values, objectives, and context. Criteria can be derived from standards, laws, policies, and other requirements. (SFS-OPAS 73, 2011, p. 11.)

Also, risk criteria should be in line with the risk management framework (SFS-ISO 31000:2018, 2018, p. 16). This thesis will deal with the framework later in subchapter 2.7.

Risk criteria for deciding whether the risk can be accepted depends on the risk attitude of project or organisation (Project Management Institute, 2013, p. 310). Risk propensity is the attitude towards taking risks and its opposite, attitude towards avoiding risks, is called risk aversion (Rohrmann, 2002). According to the Project Management Institute (2013, pp. 310-211), risk attitude may be influenced by:

- Risk appetite, which is the degree of uncertainty a project is willing to take in pursuit of objectives.
- Risk tolerance, which is the amount, volume, or degree of risk that project will withstand if risk realises.
- Risk threshold, which is the level of likelihood or impact of an event that project may have a specific interest. Below that risk threshold, the project organisation will accept the risk, and above, it will not tolerate the risk.

When evaluating the significance of a risk compared to other existing risks, an estimate of the magnitude of a risk is compared to risk criteria. These risk criteria are directly related to thresholds set around the objectives of the project. In addition to the magnitude of risk, other relevant factors for estimating the significance of risk are, for example, sustainability, ethical and legal criteria, the effectiveness and costs of controls, and the views of stakeholders. There are different techniques for deciding whether the risk can be accepted, evaluating the significance of risk, and deciding between options. (SFS-EN IEC 31010:2019, 2019, p. 15.) These techniques were introduced in subchapter 2.3.

Communication and consultation

The purpose of communication is to assist the project's stakeholders in increasing their knowledge and understanding about risks, whereas consultation seeks to obtain feedback and information to support decision-making. Communication and consultation bring different areas of expertise together, which ensures, for example, that different views are appropriately considered when defining risk criteria and evaluating risks. Communication and consultation should take place throughout all steps of the risk management process. (SFS-ISO 31000:2018, 2018, pp. 14-15.)

Risk assessment

Risk assessment means the overall process of risk identification, risk analysis, and risk evaluation (SFS-ISO 31000:2018, 2018, p. 16). The process is illustrated in Figure 9. Risk identification, analysis, and evaluation will be dealt with more detailed in sequential subchapters 2.5.1, 2.5.2, and 2.5.3. Risk assessment process leads to risk treatment, which will be introduced later in this chapter and more detailed in chapter 2.6.

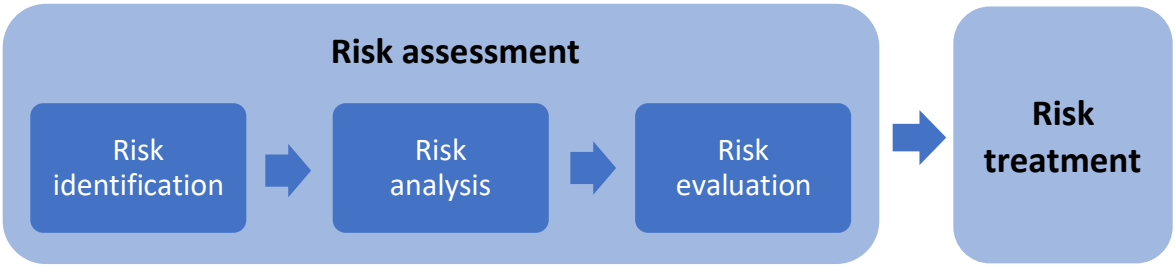

Figure 9. Risk assessment process.

The purpose of **risk identification** is to find and describe risks that the project may be facing. **Risk analysis** aims to comprehend the nature and characteristics of risk that has been found in risk identification. Where appropriate, also the level of risk can be determined. Risk analysis provides the basis for risk evaluation. **Risk evaluation** is the process where the results of risk analysis are compared to defined risk criteria in order to determine whether the consequences of risk are acceptable or tolerable. Risk evaluation assists with the decision about risk treatment. (SFS-OPAS 73, 2011, pp. 11-13.) Figure 10 clarifies the risk assessment process.

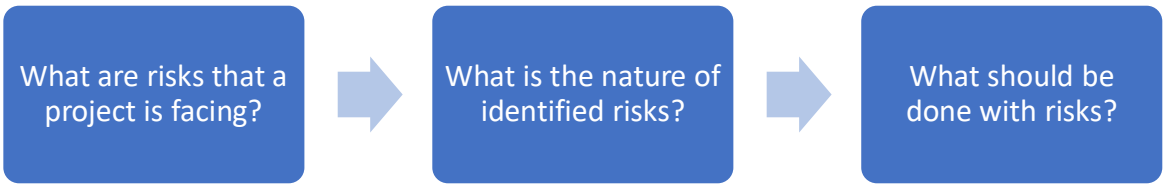

Figure 10. Risk management process presented in questions.

Risk treatment

Risk assessment process leads to risk treatment, which will be dealt with more detailed in subchapter 2.6. Risk treatment aims to select and implement options for addressing the risk (SFS-ISO 31000:2018, 2018, p. 18).

Monitoring and review

SFS-ISO 31000:2018 (2018, p. 19) defines that the purpose of monitoring and review is *"to assure and improve the quality and effectiveness of process design, implementation and outcomes."* The component aims to ensure that the process is suitable for the business, and it is working as planned (ISO/TR 31004:fi, 2014, p. 64). Monitoring and review of the risk management process should be a planned part of the risk management process, and it should take place in all stages of the risk management process. Tangible things that this phase includes are planning, collecting and analysing information, recording results, and providing feedback. In addition to the evaluation of the risk management process, organisations should also monitor and review its risk management framework. (SFS-ISO 31000:2018, 2018, p. 19.) The risk management framework is introduced later in chapter 2.7. The review of the framework should consider various of aspects, such as, is the risk management plan implemented as planned, does the level of risk corresponds to criteria, are resources enough, have lessons been learned, and are the objectives set out for risk management being achieved. (ISO/TR 31004:fi, 2014, p. 64.)

Recording and reporting

The risk management process and outcomes achieved through it should be recorded and reported with the appropriate method. The purpose of reporting and recording is to improve the communication about risk management activities and outcomes across the organisation. In this thesis, this also means from one project to another project. This component of the process also seeks to provide information to support decision-making and to improve risk management activities. One important goal is to encourage interaction between stakeholders. (SFS-ISO 31000:2018, 2018, p. 20.)

There are several techniques for recording and reporting, such as risk register, consequence/ likelihood matrix, S-curve, and bow tie analysis (SFS-EN IEC 31010:2019, 2019, p. 37). **A risk register** is used to record information about individual risks that the project is facing. Risk register generally includes a short description of the risk, source of risk, statement of the likelihood of consequences occurring, and how risks are being controlled. (SFS-EN IEC 31010:2019, 2019, p. 112.) Existence of the risk register is the primary evidence that risk management is taking place on a project. When the risk register exists, risk management can be monitored and reviewed. The risk register can also provide a background of experience for future projects. (Morledge & Adrian, 2013, p. 197.) **A Consequence/likelihood matrix** (also called risk matrix) is a technique for displaying the significance of risk according to their consequence and likelihood (SFS-EN IEC 31010:2019, 2019, p. 113). Consequence/likelihood matrix is presented more detailed later in chapter 2.5.2. **S-curve** technique generates a graph with the consequence and likelihood of risk as variables. From S-curve, the likelihood that consequences will exceed a particular value can be seen. Thus, it can be used to consider the acceptability of risk. (SFS-EN IEC 31010:2019, 2019, p. 117.) **Bow-tie analysis** is a graphical description of paths from the causes of an event to its consequences (SFS-EN IEC 31010:2019, 2019, p. 60). An example of a bow-tie analysis is presented in Figure 11.

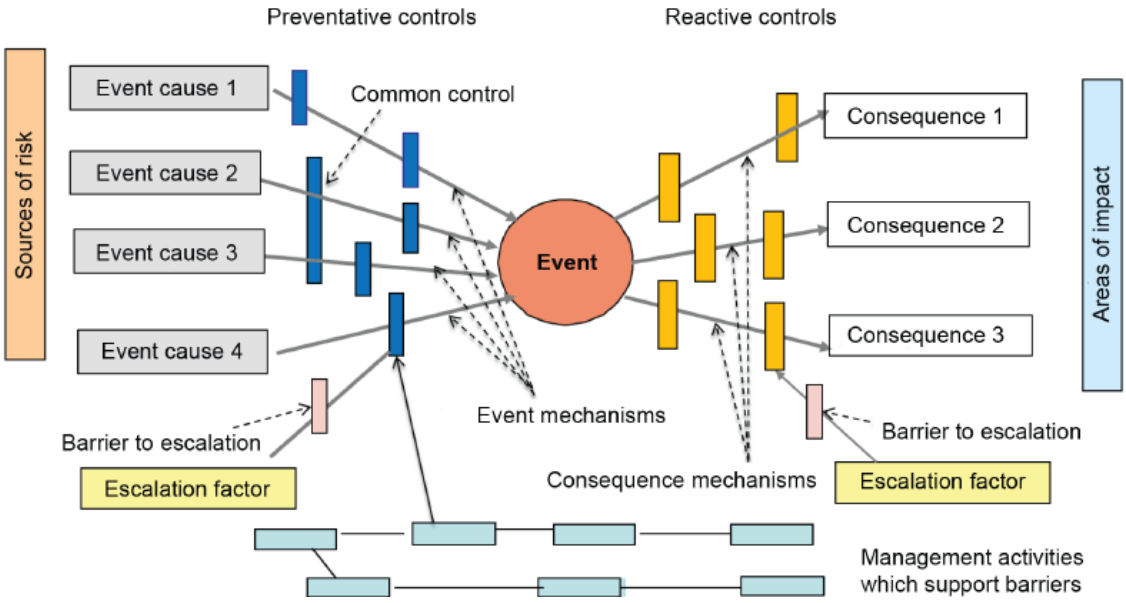

Figure 11. An example of bow-tie analysis (SFS-EN IEC 31010:2019, 2019, p. 61).

2.5 Risk assessment

Risk assessment is the overall process of risk identification, risk analysis, and risk evaluation. Effective risk assessment is conducted iteratively, systematically, and collaboratively with the knowledge of stakeholders. All stages of risk assessment demand the best available information to succeed. Information should be relevant, appropriate, and up to date. (SFS-ISO 31000:2018, 2018, p. 16.) This chapter introduces these three stages of risk assessment. Within each stage, a couple of suitable risk management techniques are introduced.

2.5.1 Risk identification

Risk identification aims to find, recognise, and describe risks that a project is facing. In order to make risk identification effective, the organisation should identify risks regardless of whether they are under its control or not. Also, the fact that there may be more than one type of outcome, which may result in different consequences should be considered. Risk should be identified as early as possible so that treatments may be implemented. (SFS-ISO 31000:2018, 2018, p. 17.)

Risk identification involves the identification of risk sources and events, and their causes and potential consequences (SFS-OPAS 73, 2011, p. 11). According to the standard SFS-EN IEC 31010:2019 (2019, p. 19) following considerations should be taken into account in the risk identification (directly quoted):

- *"What uncertainty exists and what its effects might be?*
- *What circumstances or issues (either tangible or intangible) have the potential for future consequences?*
- *What sources of risk are present or might develop?*
- *What controls are in place and whether they are effective?*
- *What, how, when, where, and why events and consequences might occur?*
- *What has happened in the past and how this might reasonably relate to the future?*
- *Which human aspects and organisational factors might apply?"*

Risk identification is dependent on various factors, such as personal tendency, experience, and available information. Therefore, if two analysts are making risk identification for the same project, they are very likely to end up with different results. (Ren, 1994.) The organisation can use a range of techniques for identifying risks. However, risk identification should be approached iteratively and methodically whatever techniques are used. Usually, risk identification techniques make use of knowledge and stakeholders' experience. (IEC 31010:2019, 2019, p. 19.)

Next, a couple of commonly used risk identification techniques are introduced. These can be used equally effectively to identify threats as well as opportunities (Hillson, 2002).

Brainstorming is a process for encouraging and stimulating a group of people to develop ideas (IEC 31010:2019, 2019, p. 40). It has been a widely used method in a group problem-solving tasks, but equally well it works for risk identification. The best outcome is ensured with an expert facilitator who sets the ground rules and explains the procedures for the members of the team. (Morledge & Adrian, 2013, p. 187.) The facilitator can provide the necessary stimulation but should not limit thinking. Criticism of the ideas is not allowed in

the brainstorming situation. The objective of the brainstorming process is to collect as many diverse ideas as possible for later analysis and evaluation. (IEC 31010:2019, 2019, p. 41.)

Delphi technique is a procedure for gaining consensus from a group. It is a structured way to collect and collate judgments on a topic through a set of sequential questionnaires (IEC 31010:2019, 2019, p. 42). Delphi technique requires a chairperson who acts as a central hub. The chairman spreads questionnaires or steers the group to generate individual lists of risks that the project may face. These questionnaires and lists are then given to all members. (Morledge & Adrian, 2013, p. 187.) The information from the first round of responses is analysed and combined, and finally circulated to members who are then able to reconsider their initial responses. The process is repeated until consensus is reached. (IEC 31010:2019, 2019, p. 42.)

Interviews allow obtaining in-depth information and opinions from individuals in a group. Answers can be confidential if necessary. According to standard SFS-EN IEC 31010:2019 (2019, p. 44), interviews are *"useful if it is difficult to get people together in the same place at the same time or if free-flowing discussion in a group is not appropriate for the situation or people involved."* Also, through interviews, it is possible to gather more detailed information than with survey or workshop. **Surveys** can generally reach more people than interviews. Surveys ask restricted questions and often offer yes or no answers, choices from a rating scale, or choices from a range of options, which allows a statistical analysis of the results. (SFS-EN IEC 31010:2019, 2019, pp. 44-45.)

Checklists allow fast risk identification and avoid problems being overlooked (Morledge & Adrian, 2013, p. 185). An example of a checklist that could be used for risk identification is presented in Figure 12.

According to the Project Management Institute (2013, p. 327), *"the primary output from risk identification the initial entry to the risk register"*. The risk register is a document where identified risks are listed and described. The risk register will be updated as the risk management process progresses. (Project Management Institute, 2013, p. 327.) The risk register was introduced earlier in subchapter 2.4.

(1) The following checklist gives both generic and specific risk issues likely to be encountered by most types of project. It is based on several more specific check lists from a variety of sources and includes lessons learned from particular projects.

(2) Each question should be considered in turn by the project team and/or risk consultant, and should be answered by one of **YES**, **NO**, **UNKNOWN,** or **NOT APPLICABLE**. Every question where the answer is NO or UNKNOWN requires a risk issue to be raised and risk mitigation or contingency actions to be identified.

(3) Respondents should consider both those aspects of the project for which they are responsible, and the complete project in the broader sense.

Project: Respondent: Date:

Risk type	**Risk area**	**Uncertainty**	**YES/NO/ UNKNOWN/ NOT APPLICABLE**	**Action**
1 Requirement	1.1 Clarity	Is the requirement well understood?		
	1.2 Volatility	Is the requirement stable?		
	1.3 Specification	Are all required specifications available and adequate?		
	1.4 Interfaces	Are all interfaces well defined and acceptable to us?		
	1.5 User	Is the required user interface clearly defined?		
2 Complexity	2.1 Project	Is the complexity of the project acceptable?		
	2.2 Size	Integration Is the size of the project manageable?		
	2.3 Integration	Has sufficient time/effort been allocated to system integration?		

Figure 12. An example checklist (edited, Morledge & Adrian, 2013, p. 186).

2.5.2 Risk analysis

Once threats and opportunities have been identified, the next part of the risk assessment process is to analyse these risks. Analysing is done in order to receive data for the last stage of risk assessment, risk evaluation. Depending on the purpose of the analysis, the availability and reliability of the information and the available resources, risk analysis can be undertaken with varying degrees of complexity and detail. (SFS-ISO 31000:2018, 2018, p. 17.) According to Morledge & Adrian (2013, p. 189), the two main questions that the analysis seeks to answer are:

- What are the consequences if the risk realises?
- What is the likelihood of the risk realisation?

Both consequences and likelihood can be expressed qualitatively or quantitively. Therefore, risks can be analysed by using qualitatively or quantitatively technique, or with the combination of both. (SFS-ISO 31000:2018, 2018, p. 17.) Qualitative analysis techniques describe risks in linguistic terms, whereas quantitative analysis deals with risks in terms of their mathematical likelihood and mathematical magnitude of consequences. (Morledge & Adrian, 2013, p. 189.) Highly uncertain events can be challenging to quantify. Therefore, in such cases, greater insight can be provided by using a combination of qualitative and quantitative techniques. (SFS-ISO 31000:2018, 2018, p. 17.) Risk analysis may consist of inaccurate information about risks associated with a project. Therefore, the analysis cannot be exact but approximate. In these cases, it can be profitable to use linguistic terms instead of real numbers. (Nieto-Morote & Ruz-Vila, 2011.)

In construction projects, qualitative methods of risk assessment are more frequently used than quantitative techniques. By combining qualitative and quantitative risk analysis techniques, risk management can be improved. (Banaitiene & Banaitis, 2012, p. 444.)

One widely used qualitative technique uses a simple ‘traffic light’ approach to evaluating the criticality and controllability of a threat. It is presented in Table 2. Threats are ranked in terms of the effort needed to control them. Threats with a ‘red-red’ profile are critical and must be handled, whereas threats with a ‘green-green’ profile are insignificant and can be ignored. (Morledge & Adrian, 2013, pp. 180-190.)

Table 2. A ‘traffic light’ approach for analysing threats (edited, Morledge & Adrian, 2013, p. 189).

	Criticality	**Controllability**
Red	Showstoppers	Very difficult
Amber	Significant but manageable	Fairly confident
Green	Minor or local impact	Very confident

In general, qualitative risk analysis seeks to describe each risk in terms of its likelihood and the impact of consequences with various linguistic scales. An example is a simplistic ‘high/low’ impact and ‘high/low’ likelihood scale that can be used for analysing of both threats and opportunities. (Morledge & Adrian, 2013, p. 189). A slightly more detailed scaling for threat analysis is presented in Table 3.

Table 3. An example of threat scaling (edited, Morledge & Adrian, 2013, p. 190).

Likelihood	Impact
Very high	Catastrophic
High	Very serious
Moderate	Moderately serious
Low	Inconvenient
Very low	Insignificant

Risks can also be analysed with graphical representations. An example is **a consequence/ likelihood matrix**, also called risk matrix. Risk matrix can be formulated when likelihood and consequence are assigned a numerical value in a specific scaling, such as from one to five. The number one means a very low consequence or likelihood, and correspondingly, the number five is a very high consequence or likelihood. By this, risks can be placed into the risk matrix. An example of the risk matrix is in Figure 13. 'The arrow of attention' (and red colour) in the middle indicates which threats and opportunities to focus first. Risks in the yellow area have medium priority. Green risks have low priority and can be ignored. According to Morledge & Adrian (2013, p. 190), if a finer distinction than what is presented in Figure 13 is needed, quantitative analysis is probably a better approach. (Morledge & Adrian, 2013, p. 190.)

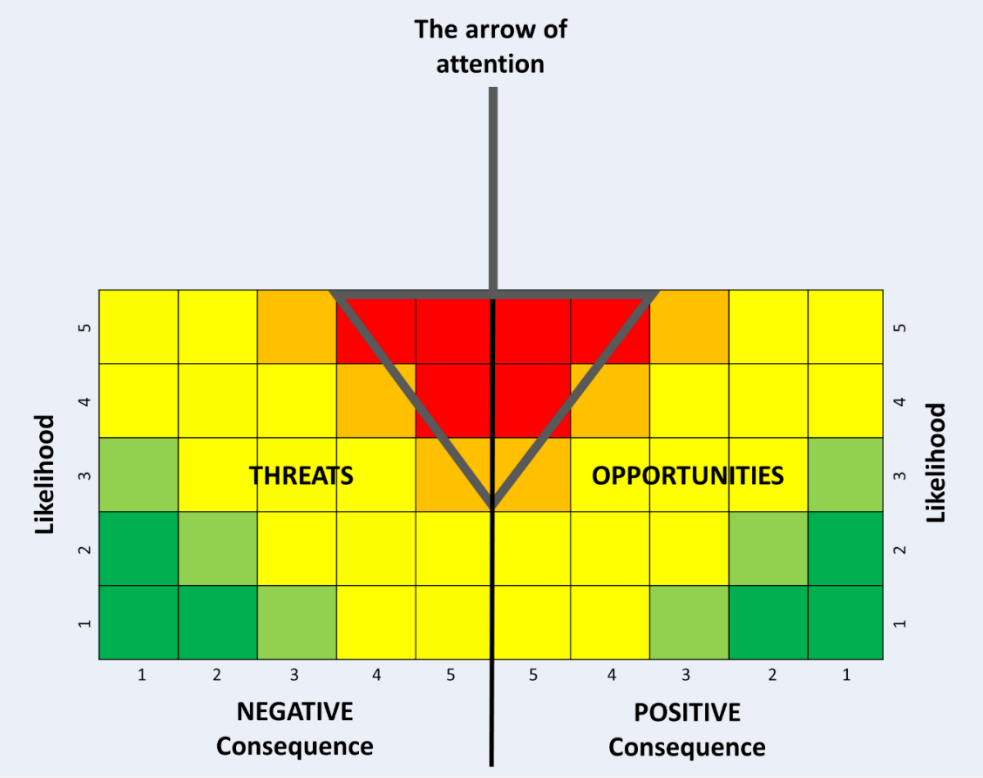

Figure 13. An example of a risk matrix (edited, Hillson, 2002).

Fuzzy sets theory is a method where data can be collected in linguistic terms such as low probability, severe impact, or high risk. These terms cannot be defined meaningfully with a precise single value. However, fuzzy sets theory transforms these terms to fuzzy sets that can be used in quantitative analysis. (Nieto-Morote & Ruz-Vila, 2011.)

In quantitative analysis the likelihood of the event occurring is given a numerical value, within scale 0 to 1. An event with a likelihood of 0 will not occur, while an event with the likelihood of 1 will definitely occur. (Morledge & Adrian, 2013, p. 190.) The consequences of a realised risk can be quantified in terms of (Morledge & Adrian, 2013, p. 190-191):

- The extent to which the project fails to meet the user requirements for performance.
- Additional time required to finish the project.
- The additional cost above the original estimate.

The most straightforward quantitative analysis bases on the definition of risk. The likelihood of risk is multiplied with the consequences in order to find out the level of risk. (Suominen, 1999, p. 46.) However, compared to qualitative techniques, quantitative techniques generally include more complicated analysis techniques, which usually require computer applications. Also, quantitative methods are less subjective compared to qualitative techniques (Morledge & Adrian, 2013, p. 191).

When analysing risks quantitatively, some calculations may involve distributions and equations with stochastic variables (Eskesen et al., 2004; SFS-EN IEC 31010:2019, 2019, p. 81). In these cases, analysing can be very complicated, even if an analytical expression can be established (Eskesen et al., 2004). In these circumstances, an approximate solution can be simulated, for example, with **Monte Carlo simulation**. Monte Carlo simulation provides a way to undertake the calculations and develop results. The results can be given, for example, as mean value or as a probability distribution, such as S-curve. (SFS-EN IEC 31010:2019, 2019, pp. 81-82.) Monte Carlo simulation is widely used within different fields of engineering branches (Eskesen et al., 2004).

2.5.3 Risk evaluation

Risk evaluation is the last part of risk assessment, and it is done before risk treatment. Risk evaluation aims to support decision-making. Risk evaluation involves comparing the results of the risk analysis with the defined risk criteria to decide where additional action is required. These actions can be the following (SFS-ISO 31000:2018, 2018, p. 18):

- To do nothing further.
- To consider risk treatment options.
- To undertake further analysis to understand the risk better.
- To maintain existing controls.
- To reconsider objectives.

SFS-EN IEC 31010:2019 (2019, p. 37) defines various techniques suitable for risk evaluation. These techniques seek to assist with selecting between options. They can also be used to evaluate the significance of the risk. Techniques that elicit the opinions of stakeholders can also be useful for risk evaluation. (SFS-EN IEC 31010:2019, 2019, p. 37.) A couple of methods for risk evaluation are introduced later in this subchapter.

Risk evaluation also includes prioritisation of identified and analysed risks. It is necessary because it would be difficult or even impossible to make a plan for dealing with every possible risk of the project. The prioritisation defines which risks should be further dealt

with and in which order. (Nieto-Morote & Ruz-Vila, 2011.) The ranking of risks can be done based on one or more of the following factors (Rumane, 2018, p. 77):

- likelihood
- consequences (impact)
- urgency
- proximity
- manageability
- controllability
- responsiveness
- variability
- ownership ambiguity.

A decision tree is a tecnique to select the most appropriate 'route' for achieving the objective of the project. It is a useful tool to assess the impact of decision-making. In construction, decision trees can be used, for example, to choose the appropriate procurement route, the method of construction or even whether to proceed with a project claim. An example of a decision three is in Figure 14. (Morledge & Adrian, 2013, pp. 192-193.)

A Cost/benefit analysis compares the total expected costs of options against their total expected benefits. It can be used in order to choose the most effective or most profitable option. The cost/benefit analysis can be qualitative, quantitative or, a combination of quantitative and qualitative elements. (SFS-EN IEC 31010:2019, 2019, p. 104.)

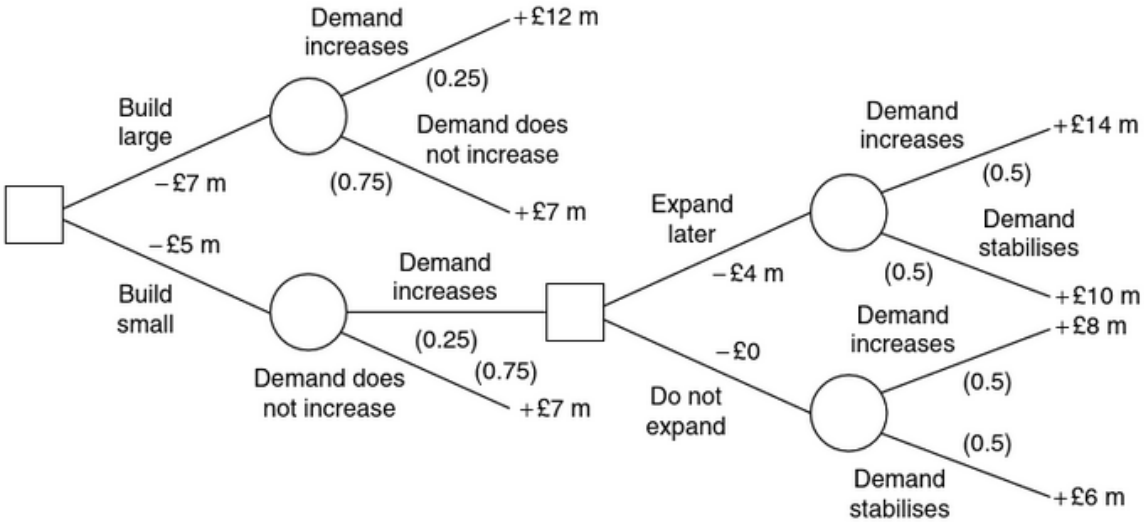

Figure 14. A decision tree where a square node depicts a choice to be made and a circular node means chance events (Morledge & Adrian, 2013, p. 193).

2.6 Risk treatment

Risk treatment is a process to modify risk. The purpose of risk treatment is to select risk treatment option and implement selected treatment. Risk treatment is an iterative process and it involves stages that are presented in Figure 15. (SFS-ISO 31000:2018, 2018, p. 18.)

Figure 15. The risk treatment process (edited, SFS-ISO 31000:2018, 2018, p. 18).

There are numerous strategies for risk, threat and possibility, treatment. When the project organisation is selecting the most appropriate treatment, it should compare the potential benefits achieved to costs, effort, or disadvantages of treatment's implementation. In addition to economic consideration, also the organisation's obligations, voluntary commitments, and stakeholder views should be taken into account when selecting the most appropriate risk treatment option. The selection should be based on values, objectives, risk criteria, and available resources of the organisation. All risk treatment options may not be appropriate in all situations. Also, risk treatment options are not necessarily mutually exclusive. (SFS-ISO 31000:2018, 2018, pp. 18-19.) Therefore, options for treating risk may involve one or more of the following risk treatment strategies (for threat: combined from ISO 31000:2018, 2018, p. 18; Morledge & Adrian, 2013, p. 195; Suominen, 1999, pp. 78-111. and for opportunity: Hillson, 2002):

- threat avoidance / opportunity exploitation
- threat reduction / opportunity enhancement
- threat transfer / opportunity sharing
- threat retention / opportunity ignoring.

Threat avoidance tries to eliminate the uncertainty that may result in negative risk. (Hillson, 2002). Usually, it means avoiding the threat by deciding not to start or continue with the activity that gives rise to the threat (SFS-ISO 31000:2018, 2018, p. 18). Threat avoidance also happens when the choice is to change to an alternative solution or remove the cause of threat (Morledge & Adrian, 2013, p. 195). A threat can also be avoided by extending the schedule, clarifying the requirements, obtaining information, improving communication, or acquiring expertise. The most radical threat avoidance strategy is to shut down the entire project. (Project Management Institute, 2013, p. 334.) **Opportunity exploitation** is parallel to threat avoidance. Exploitation aims to make the opportunity to definitely occur. In other words, it means that the likelihood is increased from 1 to 100. (Hillson, 2002.)

Threat reduction is a treatment strategy where the likelihood or consequences of a negative, risky event is reduced (Suominen, 1999, p. 81). Typically, it is more effective to take actions to reduce the likelihood or impact of a risk occurrence in early phases of a project than repair

the damage after the risk has occurred. Examples of threat reduction measures are choosing a more stable supplier, adopting more simple processes, and conduct tests and prototypes. (Project Management Institute, 2013, p. 345.) Threat reduction is the most frequently used threat treatment strategy in construction projects (Lyons & Skitmore, 2004). An opposite to threat reduction is **opportunity enhancement**, which strives to increase the likelihood and positive consequence in order to maximise the positive effects on the project. (Hillson, 2002.)

Threat transfer is implemented when the threat is transferred to the third party, usually to a party that can deal with the threat best. Treat transfer does not eliminate the negative risk. It only transfers the responsibility of its management and consequences to another party. (Morledge & Adrian, 2013, p. 195.) Threats can also be partly transferred, namely shared, with a different party (Perry, 1986). With opportunities, the corresponding strategy is called **opportunity sharing**, in which an organisation tries to find a partner who is able to manage the opportunity with maximation of the positive consequences and likelihood. With sharing, the benefits are shared to another party similarly as with threat transfer penalties are passed to another party. (Hillson, 2002.)

There are three threat transfer methods that contractors typically use in construction. The first is threat transfer from contractor to insurance companies through insurance. A threat can also be transferred from contractor to subcontractor through subcontraction. The last transfer method is the transfer from contractor to client or designer with a particular project delivery method. (Perry, 1986.)

Threat retention is a treatment strategy where a threat is retained by the informed decision, and the project organisation does not take any actions unless the negative risk occurs (Morledge & Adrian, 2013, p. 196). This strategy is occasionally adopted if it is not possible or cost-effective to choose any other strategy (Project Management Institute, 2013, p. 334). In these cases, the threat should be carefully recorded and monitored continuously. Threats can also be taken in order to pursue an opportunity. (SFS-ISO 31000:2018, 2018, p. 19.) **Opportunity ignorance** is a parallel strategy to threat retention. With opportunities, this means that minor opportunities are ignored. (Hillson, 2002.)

In construction projects, one critical risk treatment-related decision is the choice of project delivery method, which can be used to threat avoidance and transfer, or to opportunity exploitation and sharing. Project delivery method refers to how a construction project is procured or tendered, the process by which design and implementation are done, and the contractual form by which responsibilities and commercial conditions are agreed. The chosen project delivery method determines how the threats and possibilities of the construction project are shared between the different stakeholders. Therefore, it also determines which tasks each party is responsible for. (RT 10-11223, 2016.)

The choice of a suitable delivery method is made in the early planning phase of the project. Usually, the owner makes the final a choice of delivery method. However, the contractor must also make sure that the project delivery method is appropriate for it. Contractor seeks to effect on the likelihood and the magnitude of the consequences of risk through contract forms. The contract that is suitable for all the projects does not exist. Therefore, stakeholders must prioritise their objectives, and choose the form that who best accomplishes the most important goal. (Peltonen & Kiiras, 1998, p. 103.)

Main project delivery methods in construction are design-build (DB), design-bid-build (DBB), construction management (CM) methods, collaborative methods, and lifecycle methods (RT 10-11223, 2016). As mentioned earlier, risk can be affected by a suitable project delivery method. However, threats do not arise from the form of the contract but from the project itself and its objectives (Peltonen & Kiiras, 1998, p. 40).

After implementing the selected risk treatment strategy, project organisations should assess the effectiveness of the treatment. Even though risk treatment is carefully planned and implemented, outcomes can be unexpected. Risk treatment can also create new risks that need to be managed. The project organisation should decide whether the remaining threat, also called residual threat, is acceptable and if it is not, what are the further treatments. Project organisation should also be aware of the extent and nature of the residual risk. (SFS-ISO 31000:2018, 2018, p. 37.)

2.7 Risk management framework by ISO 31000:2018

According to the standard SFS-ISO 31000:2018, the effectiveness of the risk management process depends on its inclusion in the governance of project organisation and decision-making. ISO has defined the framework that aims to assist the organisation in integrating the process into its operations. (SFS-ISO 31000:2018, 2018, p. 9.) The risk management framework refers to processes and components in the management system of a company that enables risk management (ISO/TR 31004:fi, 2014, p. 58). Development of risk management framework includes *"integrating, designing, implementing, evaluating and improving risk management across the organisation"* (SFS-ISO 31000:2018, 2018, p. 28). The framework should concern in addition to the organisational level, also the project level to enable effective project risk management. However, the focus of this chapter is on the organisation level because the organisation should provide a fertile framework for project risk management. The components of the risk management framework are presented in Figure 16. Next, these components are dealt with.

Figure 16. The risk management framework (edited, SFS-ISO 31000:2018, 2018, p. 9).

Leadership and commitment

Top management and board of the company should ensure that risk management is integrated into all organisational activities. They should show leadership and commitment through applying and implementing all components of this framework. They should also create a risk management policy that establishes a course of action. To make risk management framework suitable for effective risk management, the board of the company should also reserve enough resources, such as time, skilled labour, and suitable tools. Furthermore, it is essential to determine who is responsible for risk management in every project. (SFS-ISO 31000:2018, 2018, p. 10.)

Integration

Risk management should be a part of *"the organisational purpose, governance, leadership and commitment, strategy, objectives and operations"* and not separated. Integration should be customised to the culture and needs of the organisation or project. In practice, integration is reflected in the fact that risk management is the responsibility of everyone in an organisation or project. (SFS-ISO 31000:2018, 2018, pp. 10-11.)

Design

When an organisation is designing its risk management framework, it should define roles, accountabilities, and responsibilities of the organisation. An organisation should consider how it can express its commitment to risk management. Furthermore, the organisation should also design how to allocate resources. Resources mean, for example, people and their competence and experience. Processes, methods, and tools that are used in risk management and professional development and training are also considered as resources. (SFS-ISO 31000:2018, 2018, p. 11.)

Implementation

When an organisation is implementing the framework, it should develop an appropriate plan that includes time and resources. It should also identify how, when, where, and by whom decisions are made across the organisation. This document is often called as decision-making instructions. An organisation should also modify the applicable decision-making processes where necessary. Lastly, an organisation should ensure that the arrangements for risk management are clearly understood and actually practised. (SFS-ISO 31000:2018, 2018, p. 13.) In the point of view of this thesis, this means the fact that every project should carry out planned risk management courses and with due diligence.

Evaluation

The organisation should "*periodically measure risk management framework performance against its purpose, implementation plans, indicators and expected behaviour*", and by this, determine whether the framework remains suitable for supporting the achievement of the objectives (SFS-ISO 31000:2018, 2018, p. 13).

Improvement

Improvement of the risk management framework means that the organisation should improve the adequacy, suitability, and effectiveness of the framework. Risk management framework should be continually adapted to address external and internal changes. If improvement needs are identified, the framework should be modified. (SFS-ISO 31000:2018, 2018, p. 13.)

2.8 Principles of effective risk management by ISO 31000

The risk management standard SFS-ISO 31000:2018 defines eight principles that need to be satisfied in order to make risk management effective. These principles are the base for effective risk management. Thus, these principles should be considered when establishing the risk management process and framework of the project. (SFS-ISO 31000:2018, 2018, p. 7.) Principles and their explanations are presented in Table 4.

Table 4. Principles of effective risk management and their definitions (compiled from SFS-ISO 31000:2018, 2018, pp. 8-9).

Principle	Definition
Integrated	Risk management is an integral part of all organisational activities.
Structured and comprehensive	A structured and comprehensive operating model for risk management contributes to consistent and comparable results.
Customised	The risk management framework and process are customised and proportionate to the organisation's external and internal context related to its objectives.
Inclusive	Appropriate and timely involvement of stakeholders enables their knowledge, views, and perceptions to be considered. This results in improved awareness and informed risk management.
Dynamic	Risks can emerge, change, or disappear as an organisation's external and internal context changes. Risk management anticipates, detects, acknowledges, and responds to those changes and events in an appropriate and timely manner.
Best available information	The inputs to risk management are based on historical and current information, as well as on future expectations. Risk management explicitly takes into account any limitations and uncertainties associated with such information and expectations. Information should be timely, clear, and available to relevant stakeholders.
Human and cultural factors	Human behaviour and culture significantly influence all aspects of risk management at each level and stage.
Continual improvement	Risk management is continually improved through learning and experience.

2.9 Risk management in construction projects

2.9.1 Characteristics of the construction industry

According to Raj & Wadsamudrakar (2018), the construction industry tends to have a poor reputation for time and cost overruns. There are many reasons for its bad reputation. The main reason is the fact that the construction industry is one of the riskiest of all types of business. (Raj & Wadsamudrakar, 2018.) When compared to many other manufacturing industries, the construction industry is subject to more risks due to the unique features of construction activities such as complicated processes, long planning and construction period, financial intensity, dynamic project organisation, and challenging environment. (Zou et al., 2006.)

Construction projects are complex and unique in terms of size, location, planning, timeframe, and project organisation (Raj & Wadsamudrakar, 2018). The project organisation is a temporary project team that is assembled from different companies, countries, and cultures, and changes with every project (El-Sayegh, 2008). There are multiple stakeholders, such as owners, designers, contractors, subcontractors, and suppliers, with various interest involved. (Raj & Wadsamudrakar, 2018.) Furthermore, construction projects require interpretation of and compliance with many laws, codes, and regulations, and they have time, cost, and quality targets to meet (Chartered Institute of Building, 2019, pp. 10-13). Thus, there are significant risks involved in construction projects.

While much of the literature emphasises the uniqueness of the construction project, Raftery (1994) brought out that most buildings consist of a similar set of construction activities. It means that most buildings are built with the same set of elements, such as substructure, frame, roof, external walls, internal partitions, and services. Furthermore, many of the materials and components are identical. However, Raftery highlights that there are also significant differences between projects: *"Despite largely common activities and processes, each project is assembled and constructed on its own site with its own physical characteristics, subject to weather conditions depending on the season, with different material specifications, and technical solutions to the problems of enclosing space."* Figure 17 depicts the similarities and differences between the two building projects. (Raftery, 1994.)

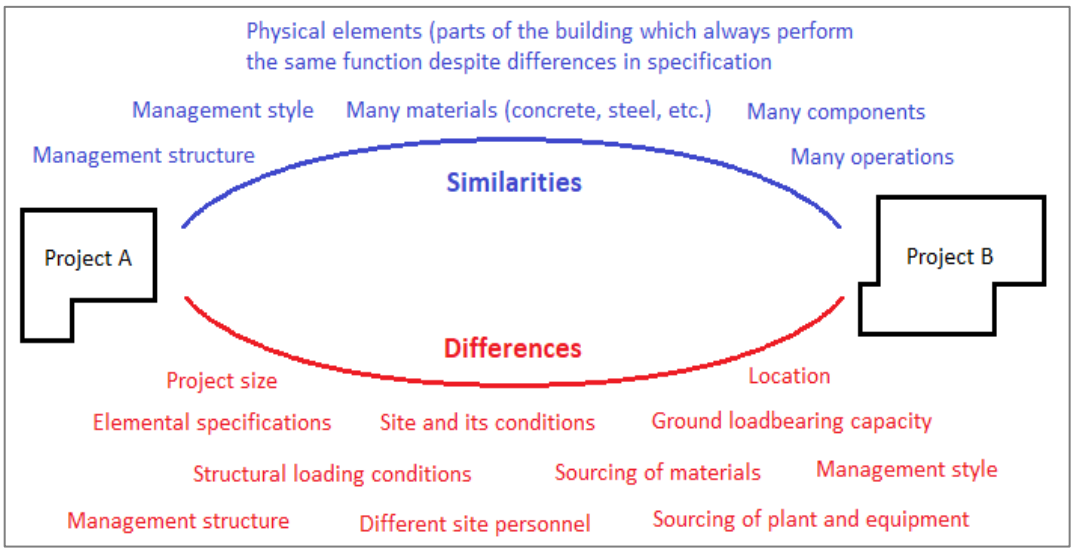

Figure 17. Project heterogeneity (edited, Raftery, 1994).

2.9.2 Risk management in construction projects

Voetsch, Cioffi, & Anbari (2004) researched project risk management and its association with the reported success of the project. Data was collected from 175 survey respondents and 12 selective interviewees. As a result, the research found a statistically significant relationship between management support for project management and reported project success. (Voetsch et al., 2004.) Also, Baloi & Price (2003) declare that risk management is a critical factor in achieving successful project management.

According to Baloi & Price (2003), the importance has become emphasised, especially nowadays, when projects tend to be more complex and the competition tougher. They presented that there is a direct relationship between effective risk management and project success since risks are assessed by their potential effect on the objectives of the project. (Baloi & Price, 2003.) Project complexity can be assumed to contribute to the number of risks and their likelihood (Bosch-Rekveldt, 2011, p. 38). So, as the complexity grows, also more risks appear.

Traditionally, contractors have used high mark-ups to cover the possible costs of risks. However, margins of contractors have become smaller, and this approach to manage risks is no longer effective. (Baloi & Price, 2003.) Furthermore, the complexity of projects is linked to the growing number of stakeholders (Taillandier et al., 2015). According to Ward & Chapman (2008), one primary source of risks in construction projects are the stakeholders. Xia et al. (2018) have argued that traditional efforts for improving risk management and stakeholder management are primarily undertaken in isolation without crossover between these two management areas. They have proposed integrating risk and stakeholder management. According to them, integration is feasible and may promote the effectiveness of both risk and stakeholder management. (Xia et al., 2018.)

There has been a somewhat research about the deficiency of risk management in construction. Lyons & Skitmore (2004) researched construction project risk management by interviews and comparison with four earlier relevant studies. They found out that the overall use of risk management among respondents was from moderate to high. The usage of risk management in the execution and planning stages of the project life cycle is higher than in the conceptual or termination phases. According to them, *"This contrasts with the view that risk management application in the conceptual phase is the most important."* They also found out that project teams are used more frequently for risk analysis, ahead of consultants and in-house specialists. According to them, the level of training in risk management techniques is only low to moderate. However, they could not identify a dominant factor that limits the implementation of risk management. All the factors nominated in their survey (cost-effectiveness, difficulty in seeing the benefits, human/organisational resistance, lack of accepted industry model for risk analysis, lack of dedicated resources, lack of expertise in the techniques, lack of familiarity with the techniques, lack of information, and lack of time) were low to moderately relevant. (Lyons & Skitmore, 2004.)

Qazi et al. (2016) found out that the risk management process implemented in the construction industry does not consider complex interaction between project complexity and risks. Although project complexity is considered an essential factor, not all aspects of the project's complexity are considered in the risk assessment process. Also, according to Qazi et al., when project managers are dealing with risks, they generally rely on their intuition and experience. The research found out that risk management in construction projects also

faces challenges such as inadequate support from senior management and the requirement of populating such sophisticated models with data. (Qazi et al., 2016.)

Several studies have shown (for example, Ibbs & Kwak, 2000; Raz et al., 2002) that risk management practices are not widely used. Zwikael & Sadeh (2007) made the point that, even though various risk assessment techniques are available, these techniques are not suitable for many industries, organisations, and projects. According to Kintore & MacLeod (1997), formal risk analysis and management techniques are rarely used due to doubts on the suitability of these techniques for the construction industry. Also, the lack of knowledge of risk management affects its usage in construction projects. (Akintoye & MacLeod, 1997.) According to Zwikael & Sadeh (2007), there may be an organisational failure in the implementation of the use of risk management tools as part of the project risk management process or a lack of risk management knowledge in project managers. According to their study, project managers tend to use more advanced techniques when the project's risk level is high. Since these techniques require time and expertise, project managers generally tend to ignore them in projects where the risk level is low. (Zwikaela & Sadeh, 2007.)

2.9.3 Risks and their categorisation in construction projects

There are many different risks in construction projects. Risk categorisation is a significant step in the risk management process because it attempts to structure the various risks affecting a construction project (Zou et al., 2006). Next, different approaches to risk categorisation are introduced and then compiled in Table 5. Finally, the most common risks that construction projects are facing are presented.

In the literature, various approaches for categorising these risks are used. One widely used approach is to divide risks **hierarchically into internal and external by the initial source of the risk**, and further into subcategories according to the nature of the risks. For example, El-Sayegh & Mansour (2015) and Tah & Carr (2000) used this approach for risk categorisation. Division to subcategories can also be done, for example, according to the stakeholder who might be the instigator of risk, such as client, designer, or contractor as El-Sayegh (2008) has done. External risks originate from outside of the project. They are relatively uncontrollable and thus require persistent forecasting and scanning. Internal risks are peculiar to a project. They are more controllable than external risks and are different in every project. (Jayasudha & Vidivelli, 2016; Tah & Carr, 2000.)

Siraj & Fayek (2019) researched common risk identification tools and techniques, risk classification methods, and common threats that construction projects are facing. They conducted a systematic literature review and a detailed content analysis of 130 selected articles from relevant academic journals published over the last three decades. They ended up categorisation that is done based on **the nature of the risk** as follows: management, technical, construction, resource-related, site conditions, contractual & legal, economic & financial, social, political, environmental, and health & safety risks. According to Siraj & Fayek, categorisation based on the nature of the risk was the most used approach among those 130 articles. (Siraj & Fayek, 2019.) Also, for example, Al-Bahar & Crandall (1990), Bhandegaonkar & Waghmare (2019), Raj & Wadsamudrakar (2018), and Tavakolan & Etemadinia (2017) used this approach.

The categorisation can be done according to **the project phase at which the risks would occur**. For example, Goh et al. (2013) divided risks into the following five categories: planning, design, procurement, construction, and hand-over phase risks. Also, Li & Zou (2011) used this approach to categorise risks.

Zou et al. (2006) categorised risks into five groups based on **their respective impact on project objectives** as follows: cost-, time-, quality-, environment-, and safety-related risks. However, according to Siraj & Fayek (2019), thus a single risk source may have an impact on more than one objective of the project, such categorisation may result in redundancy.

Furthermore, the categorisation can be done based on **the stakeholders of the project who might be the instigator of the risk**. For example, Zou & Zhang (2009) and Wu et al. (2017) used this approach.

Risks can be divided into **macro-, meso-, micro-level risks,** as Hwang et al. (2013) have done. Risks in macro-level beyond the system boundaries of the project. Examples of macro-level risk can be 'weather' and 'geological conditions'. Meso-level risks, such as 'design deficiency' and 'construction time delay' are risks within the project, and they are directly related to the nature of the project. Finally, risks that are related to the stakeholders of the project, such as 'organisational & communication risk', are categorised to micro-level. (Hwang et al., 2013; Siraj & Fayek, 2019.)

Risks can also be handled without categorisation. In this case, they are just listed. An example is research by Qazi et al. (2016).

Despite the categorisation used, various approaches organise risks using a risk breakdown structure (RBS) (Siraj & Fayek, 2019). In RBS, identified risks are hierarchically arranged into risk categories and subcategories, that identify the areas or causes of risk sources in order to make the handling and presentation easier. (Project Management Institute, 2013, p. 317.)

Table 5. Approaches for risk categorisation in construction projects.

Author	Categorisation
Al-Bahar & Crandall, 1990	Based on the nature of the risk to acts of God, physical, financial & economic, political & environmental, design, and construction risks.
Bhandegaonkar & Waghmare, 2019	Based on the nature of the risk to technical, financial, management, logistic, socio-political, environmental, and construction risks.
El-Sayegh, 2008	Hierarchically based on the initial source of risk to - internal risks (and further based on the stakeholders of the project who might be the instigator of the risk to the owner, designer, contractor, subcontractor, and supplier risks) and - external risks (and further based on the nature of the risk to political, social & cultural, economic, natural, and other risks).
El-Sayegh & Mansour, 2015	Hierarchically based the initial source of risk to - internal risks (and further based on the nature of the risk to technical, site, and commercial risks) and - external risks (and further based on the nature of the risk to political, social, environmental, and socio-economic risks).
Goh et al., 2013	Based on the project phase at which the risks would occur to planning, design, procurement, construction, and hand-over phase risks.
Li & Zou, 2011	Based on the project phase at which the risks would occur to study, tendering, financing, design, construction, operation, and transfer phase risks.
Raj & Wadsamudrakar, 2018	Based on the nature of the risk source to commercial, financial, legal, political, social, environmental, communications, geographical, geotechnical, construction, technological, operational, demand & product, and management risks.
Tavakolan & Etemadinia, 2017	Based on the nature of the risk source to financial, contractual, design, HSE (health, safety, environment), management, construction, social & political, external, and procurement & supply risks.
Siraj & Fayek, 2019	Based on the nature of the risk source to management, technical, construction, resource-related, site conditions, contractual & legal, economic & financial, social, political, environmental, and health & safety risks.
Tah & Carr, 2000	Hierarchically to - external risks, - internal risks, and further as presented in Figure 18.
Qazi et al., 2016	Risks are listed without any categorisation.

Wu et al., 2017	Based on the stakeholders of the project who might be the instigator of the risk to client, designer, contractor, subcontractor, and government agencies risks.
Zou & Zhang, 2009	Based on the stakeholders of the project who might be the instigator of the risk to client, designer, contractor, subcontractor, government bodies, and external environment risks.
Zou et al., 2006	Based on the respective impact of the risk source on project objectives to cost-, time-, quality-, environment-, and safety-related risks.

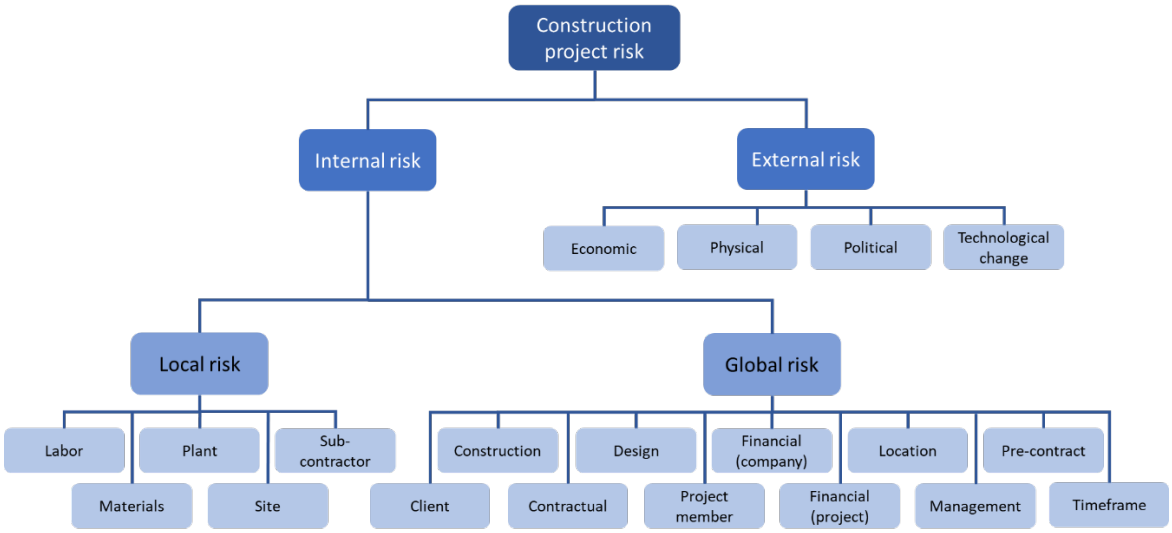

Figure 18. Hierarchical construction project risks categorisation by Tah & Carr (edited, 2000).

Next, the key threats in construction projects are considered. As introduced earlier, Siraj & Fayek (2019) researched key threats in construction projects. They conducted an extensive review and content analysis on the selected 130 articles and found a total of 571 threats that construction projects are facing. The frequencies of risks were used to reflect how common these threats are in the construction industry. The top ten most frequently mentioned threats in the selected articles were (Siraj & Fayek, 2019):

1. Unpredicted changes in the inflation rate
2. Design errors and poor engineering
3. Changes in government laws, regulations, and policies affecting the project
4. Adverse weather conditions
5. Unpredicted adverse subsurface conditions
6. Unavailability of a sufficient amount of skilled labour in the project region
7. Force majeure
8. Poor workmanship and construction errors leading to rework
9. Unavailability or shortage of expected materials
10. Project funding problems.

In addition to the research by Siraj & Fayek, there have been several studies about the most common risks in construction projects. For example, Jayasudha & Vidivelli (2016) ended up with the following ranking:

1. Incomplete design
2. Inadequate site investigation
3. Improper project planning and budgeting
4. Inadequate specification
5. Excessive approval procedures in administrative government departments
6. The contractor does not pay worker wages in due time
7. Tight project schedule
8. Inappropriate time allocation
9. Insufficient time to prepare bid
10. Unsuitable construction program planning.

Moreover, Xou et al. (2006) came to the following ranking:

1. Tight project schedule
2. Design variations
3. Excessive approval procedures in an administrative government department
4. High performance or quality expectations
5. Inadequate program scheduling
6. Unsuitable construction program planning
7. Variations of construction programs
8. Low management competency of subcontractors
9. Variations by the client
10. Incomplete approval and other documents.

However, studies show that the most common risks are usually linked to overly tight schedule and improper planning, such as technical, schedule, cost, and safety planning. Variation in research results depends, for example, because of the timing of the research, project size distribution, location, and project delivery method distribution.

As a conclusion, the literature review aimed to give an answer to the first research subquestion, which was as follows: “What is the risk management process defined by ISO 31000:2018?” According to the risk management standard ISO 31000:2018 risk management process is a process that aims to create value and protect the project and organisation in question. In practice, the purpose of risk management is to decrease the consequence and likelihood of negative events and increase the consequence and likelihood of positive events in the project. Risk management process by ISO consists of components that are risk assessment; risk treatment; scope, context, and criteria; communication and consultation; monitoring and review; and recording and reporting. The aim of these components, in addition to dealing with individual risks, is to monitor and review the process itself in order to improve it continuously. To make risk management effective it should be an integral part of all organisational activities, and it should be integrated into the structure, operations, and processes of the project and its organisation.

3 Empirical study

3.1 Methodology for the empirical study

The empirical study of this thesis is conducted as a case study. A case study is typically used in order to gather detailed information. A case study is a commonly used method to research processes. Typically, it includes many data collection methods. (Hirsjärvi et al., 2009, pp. 134-135). A typical feature of a case study is a tendency to seek theoretical generalisation. However, it has been criticised because of the difficulty in carrying out statistical generalisation. In a case study, a holistic understanding of a case is more important than statistical generalisation. Furthermore, it is criticised for its subjectivity and difficulty of reproduction. (Aaltola & Valli, 2007.) However, the case study approach can be considered as an appropriate method in the context and objective of this thesis.

This case study uses a case company in order to gather data. This approach is selected because it provides detailed information about the process that an actual construction company is using. Besides, the case company does in-depth research about actual operations and practises in projects possible. Also, by extensively researching the subject throughout the case company, it is possible to find out if there are divergences of practices inside the company.

The case company of this thesis is NCC Building Finland, which is one of the business areas of NCC Group. NCC Building Finland consists of six departments which are presented in Table 6. NCC Group is one of the leading construction, real estate, and infrastructure companies in Northern Europe. The vision of NCC is to renew its industry and provide superior sustainable solutions. The values of the company are honesty, respect, trust and pioneering spirit. NCC Building Finland is a suitable case company for this research because its project risk management process is based on the ISO 31000 standard.

Table 6. Departments of NCC Building Finland.

Abbreviation	Department	Definition
AR	Residential Construction Helsinki	New residential construction in the Helsinki metropolitan area
TR	Non-Residential Construction Helsinki	Offices, public, and commercial premises in the Helsinki metropolitan area, Häme, and Uusimaa
KR	Refurbishment Helsinki	Renovations in Helsinki metropolitan area
ER	Special Projects	Industrial and other special projects throughout Finland
AV	Regional Operations Middle	Building and renovating of residential and office properties in regional units of Oulu, Kuopio, and Jyväskylä
AL	Regional Operations West	Building and renovating of residential and office properties in regional units of Turku and Tampere

This case study is done as mixed-model research. Mixed-model research is done by using multiple methods, meaning that more than one data collection technique and associated analysis technique is used. Instead of using purely qualitative or quantitative data collection methods (multi-method), mixed-model research uses both qualitative and quantitative techniques. Furthermore, instead of mixed-methods research, where qualitative and quantitative methods are not combined (quantitative data is analysed quantitively and quantitative quantitatively), this thesis uses mixed-model research, where qualitative data collection techniques and analysis procedures are mixed to quantitative ones. It means that qualitative data can be quantified by converting it to numerical format and then analysed statistically. Respectively, also quantitative data can be qualified. (Saunders et al., 2009, pp. 152-153.)

According to Hirsjärvi et al. (2009, pp. 136-137), qualitative and quantitative research complement each other, and in practice, it is difficult to distinguish precisely between them. They can be considered as complementary approaches. Qualitative research can be used as a preliminary test for quantitative research, or as this thesis is using, qualitative and quantitative research can be used side by side, as parallel methods. (Hirsjärvi et al., 2009, pp. 136-137.)

This thesis utilises three different data collection methods, which are a documentary study, interviews, and a questionnaire. The documentary study produces qualitative data. Interviews provide qualitative data that is partly quantified. Furthermore, the questionnaire produces both qualitative and quantitative data. The mixed-model research is selected to be the approach because of the thesis' broad subject. However, the emphasis is on qualitative data due to the descriptive nature of the thesis. This chapter is divided based on the data collection methods so that subchapter 3.2 concerns data achieved from documents and subchapter 3.3 data from interviews and a questionnaire.

All observations and data are collected in Finnish and then translated to English. Because the case company operates in Finland, also most of the documents and materials are available in Finnish. Also, most of the employees of the case company speak Finnish as their mother tongue. Thus, interviews and the questionnaire were conducted with the langue, that most of the respondents were most comfortable with. By this, the observations were most comprehensive, and misunderstandings minimised. Translations were done with care and precision so that the meaning of the sentences does not change. The vocabulary was sought to keep as the typical vocabulary of the industry.

Methodology for the documentary study

The first part of the empirical research is the documentary study. It considers documents related to project risk management of the case company in order to find out what is the project risk management process that the case company defines. Thus, the documentary study aims to collect data to level 2. Obtained data aims to give an explanatory answer to the research subquestion two, which is: "SRQ 2: What is the project risk management process defined by the construction company?"

This section of the empirical research is purely qualitative research. A typical feature of qualitative research is its aim to describe the target comprehensively. (Hirsjärvi et al., 2009, p. 161). It is also the purpose of this part of empirical research.

This documentary study started by looking for all available documents related to risk management. The material was searched from the case company's operating system, internal website, and personnel. Then, the documents were carefully read thought and materials relevant to the research questions were selected. Sources for information are presented in Table 7. The primary source for the documentary study was the tool's instructions (Document 2), which also include information about the risk management process itself. Finally, relevant material was translated and modified suitable for presentation.

Table 7. Documents of the case company used in the empirical study.

Document	Name	Source	Format	Length	Updated
Document 1	Riskianalyysi (Risk analysis)	Operating System	Internet page	~1 page	13.4.2017
Document 2	Riski- ja Mahdollisuusanalyysi – Pro3 työkalu (Threat and opportunity analysis – Pro3 tool)	Operating system	PowerPoint presentation	19 pages	13.4.2017
Document 3	TJK Koulutusohjelma (Production management training)	Personnel	PowerPoint presentation	67 pages	3.12.2019

Methodology for interviews and questionnaire

The second part of the empirical research includes interviews and a questionnaire. These data collection methods are used in order to gather data mainly to level three, which corresponds to the actual risk management operations in projects. The tool for risk assessment, R&M-analysis tool, was already described in the documentary study. Interviews and the questionnaire are used to collect data from the tool's users' point of view. The research subquestion to be answered is: "RSQ 3: How is risk management implemented in practice in projects?"

An interview is a widely used data collection method, where the researcher interacts directly with the interviewee. The most significant benefit of the method is considered to be the flexibility in collecting the data. (Hirsjärvi et al., 2009, pp. 204-207.) An interview is a suitable choice to be the data collection method for these research questions. It is justified by the assumption that if one wants information about actual risk management practices and actions in projects, it is useful to ask the authors themselves. Other option would have been an observation, but then the subject could not have been studied so extensively and with a large sample. According to Hirsjärvi et al. (2009, p. 205), an interview is often selected to be the method when the subject is relatively little studied and thus, it is difficult for a researcher to know the directions of the answers in advance. Case company's risk management has not been studied this widely before. Also, the researcher did not know in advance what the perception related to risk management is going to be. However, the most crucial justification for choosing interviews is that it is a highly flexible method. Thus, it possible to ask supplementary questions and justifications for opinions. Also, it is possible to focus more on questions that interviewees have more to say and leave others in the background.

The drawback of the interviews is the slowness of their implementation and the analysis of the data obtained. Also, interviews contain many sources of error that may be due to the interviewer, the interviewee, or the situation itself.

The interview process of this thesis started with a selection of employees to be interviewed. The researcher made the selection with the help of the Head of Risk Management of the case company, Ilkka Forsell. His help was used due to his long career and extensive knowledge of case company's personnel. The interviewee candidates were selected evenly from all the six departments with a large scale of job titles. Interviewee candidates were chosen so that they have diverse backgrounds; for example, years worked in the case company or years worked with the current job title. Interviewees breakdown by these terms is presented in Figure 19. Also, when selecting candidates to be interviewees, the aim was to identify individuals who could have an opinion on the subject and could possibly express their opinions honestly. It is typical for qualitative data collection methods to select the target set appropriately, not by random sampling (Hirsjärvi et al., 2009, p. 164).

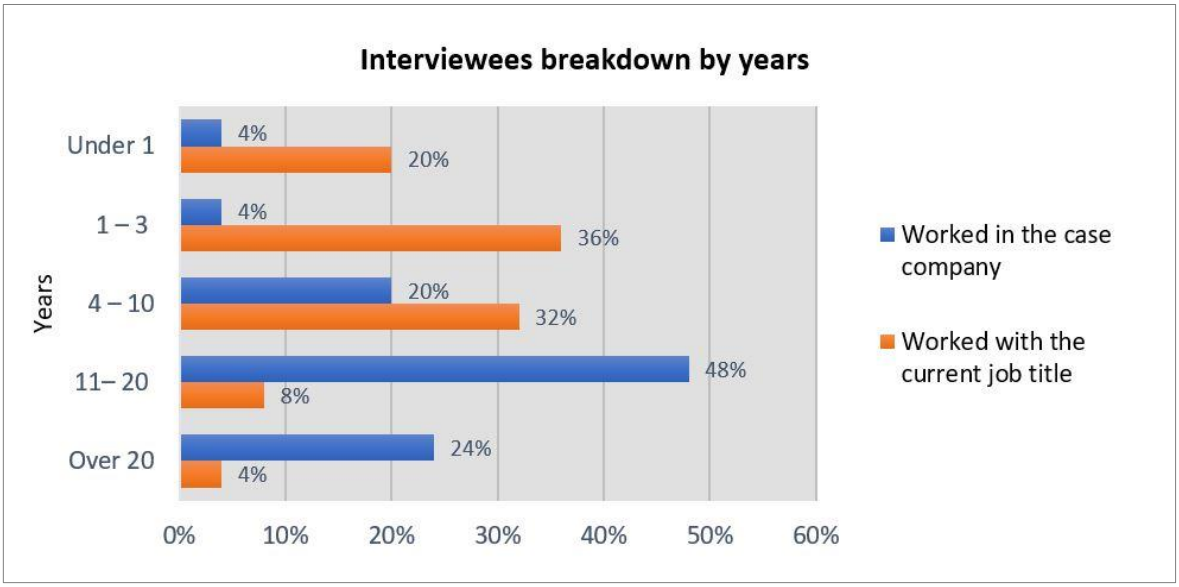

Figure 19. Interviewees breakdown by years worked in the case company and worked with the current job title.

The selected candidates were approached through phone calls. All candidates agreed to be interviewed. Each of the interviewees was sent the body of interviews along with short information about the thesis and purpose of the interview beforehand by e-mail. It was made in order to make sure that the interviewees were aware of the contents of the interviews. Furthermore, it enabled interviewees to prepare themselves for the interviews if they felt so. The interviewees were stressed that despite the extensive list of questions, the interview situation is semi-structured, and thus, the interview does not have to follow the given pattern. Besides, it was told that interviews are handled entirely anonymously. A total of 25 people was interviewed. Full list of interviews, including their date, place, duration, and interviewee's job titles is in Table 8. All interviewees considered that risk management is part of their job description and told they have participated in the risk assessment of a project.

Table 8. Interviews, their dates, durations, places, and job titles of interviewees.

Inter-viewee	Date	Dura-tion	Place	Job title
1	12.12.2019	27:08	NCC Building	Construction manager
2	16.12.2019	33:04	NCC Building	Quality and environment manager
3	16.12.2019	36:35	NCC Building	Cost estimation manager
4	17.12.2019	41:40	Skype meeting	Building manager
5	17.12.2019	25:38	NCC Building	Construction manager
6	18.12.2019	36:03	Site	Site manager
7	18.12.2019	36:03	Site	Site engineer
8	18.12.2019	29:20	NCC Building	Cost estimation manager
9	18.12.2019	25:39	Skype meeting	Construction manager
10	19.12.2019	51:07	Site	Construction manager
11	19.12.2019	22:24	Site	Site manager
12 *	19.12.2019	12:50	NCC Building	After sales manager
13 *	19.12.2019	12:50	NCC Building	After sales manager
14	19.12.2019	37:46	NCC Building	Construction Manager
15	20.12.2019	33:06	Skype meeting	Site manager
16	20.12.2019	48:55	NCC Building	Unit manager
17	7.1.2020	40:41	NCC Building	Operations manager
18	7.1.2020	30:00	Skype meeting	Regional manager
19	7.1.2020	59:54	NCC Building	Operations manager
20	7.1.2020	16:29	Skype meeting	Head of production
21	8.1.2020	31:50	Skype meeting	Regional manager
22	8.1.2020	16:50	Skype meeting	Cost estimation manager
23	8.1.2020	23:21	Skype meeting	Construction manager
24	10.1.2020	38.58	NCC Building	Construction manager
25	10.1.2020	22:27	Skype meeting	Site manager

* The interview was conducted as a group interview.

The interview questions were broadly drafted since the topic of the research is extensive. The questions were detailed in order to achieve a detailed description of the subject. The interview was divided into the sections described under. The entire interview pattern is at the end of this thesis as an appendix (Appendix 1).

- **Background of the interviewee**
- **Project risk management generally:** This section included questions that aimed to find out what interviewee's general perception about risk management is: its meaning, importance and benefits.
- **Project risk management in the case company:** Questions in this section concerned regular risk management operations and courses of action in projects.
- **Risk assessment and treatment:** This section focused on risk identification, analysis, evaluation, and treatment.
- **Risk management tool (R&M-analysis)**
- **Risk management competence:** Questions related to acquirements, training and instructions.
- **Other:** This section included questions about the flow of information, resources and monitoring and review of the risk management process.
- **Free comment**

Most of the interviews were kept in the main office of the case company, NCC Building. Because of the geographical scope of the interview, respondents were located in the whole Finland region, and part of the interviews was conducted as Skype meetings. Also, four of the interviews were held at the site's office in order to ease the interviewees' effort for the interview. Interviews were kept as an individual, except for one that had two interviewees.

Interviews started with an explanation about how the interview will be conducted. It included a reminder about the anonymous of the interview and data obtained through it. Interviewees were asked to be honest in order to get valuable data. Also, permission to record the interview with a smartphone's recording application was asked.

Interviews were conducted as a semi-structured interview, where a researcher can have a list of themes or questions to be covered, although these may vary from interview to interview. Some questions may be omitted, and additional questions asked. Also, the order of the questions may vary depending on the flow of the conversation. (Saunders et al., 2009, p. 320.) The semi-structured interview was selected due to flexibility. Because interviewees were from diverse backgrounds, worked at different phases, and had different competence, it was beneficial that not all the questions had to be discussed. Also, because interviews were used to gather mostly qualitative data, this interview method allowed the interview to focus on topics that interviewees considered they have an opinion or knowledge.

The analysing process started by listening to all the audio-recorded data from the interviews. It was done as soon as possible after the interview. Pertinent data were transcribed word by word into written form to Excel sheet. Transcription was done according to the interview number and subject. It was done in order to make the review of answers easier with Excel's data filtering function. Transcription is highly time-consuming, and it was the most time-consuming step of the entire empirical study. Part of the data from interviews was quantified in order to see portions of similar responses. If the data from interviews is quantified, it is marked as follows: (x/y), where x represents the number of similar answers and y represents the number of interviewees the subject was talked about.

After all the interviews were transcribed, they were analysed by categorising them based on the theme. When data obtained from interviews were tentatively analysed, an online questionnaire was conducted. Because the selection of the interviewees was subjective, the questionnaire was conducted in order to produce more objective data. An objective and a large sample of questionnaire respondents yielded relatively reliable numerical data.

A questionnaire is a data collection method where every respondent is asked the same set of questions. Data obtained from a questionnaire is usually analysed quantitatively. The advantage of a questionnaire is that it allows obtaining extensive research data because many people can do a questionnaire, and it can concern various subjects. (Hirsjärvi, 2009, pp. 139-195.) This thesis uses an online questionnaire. Thus, the analysing process of data achieved from the questionnaire can be fast due to computer analysis. The questionnaire has been criticised, for example, for not being sure that all respondents have conducted the questionnaire truthfully and carefully. Also, there might be the adequacy of response rates of the questionnaire. (Hirsjärvi et al., 2009, p. 195.)

The questionnaire was created by Surveypal. Answer options in the questionnaire were created based on the interviews. The body of the questionnaire is at the end of this thesis as

an appendix (Appendix 2). The questionnaire was sent as a link to email lists of the case company. The link was sent to all cost estimation managers, purchasing managers, construction managers, responsible site managers, and site engineers across all six departments of the case company. There was a sought to select many different job titles who work closely on projects to respond to the questionnaire. The questionnaire was sent to the graduates in order to ensure that the respondents were sufficiently skilled. As in interviews, the department was not restricted in order to receive data throughout the company. The link was sent to 258 recipients. A total of 107 people responded to the questionnaire, representing a response rate of 40 %. The sample can be considered comprehensive and reliable.

Figure 20 represents the questionnaire respondent's breakdown by years worked in the case company and years worked with the current job title. Figure 21 presents the questionnaire respondent's breakdown by the job title. Next, the results of the empirical study are presented.

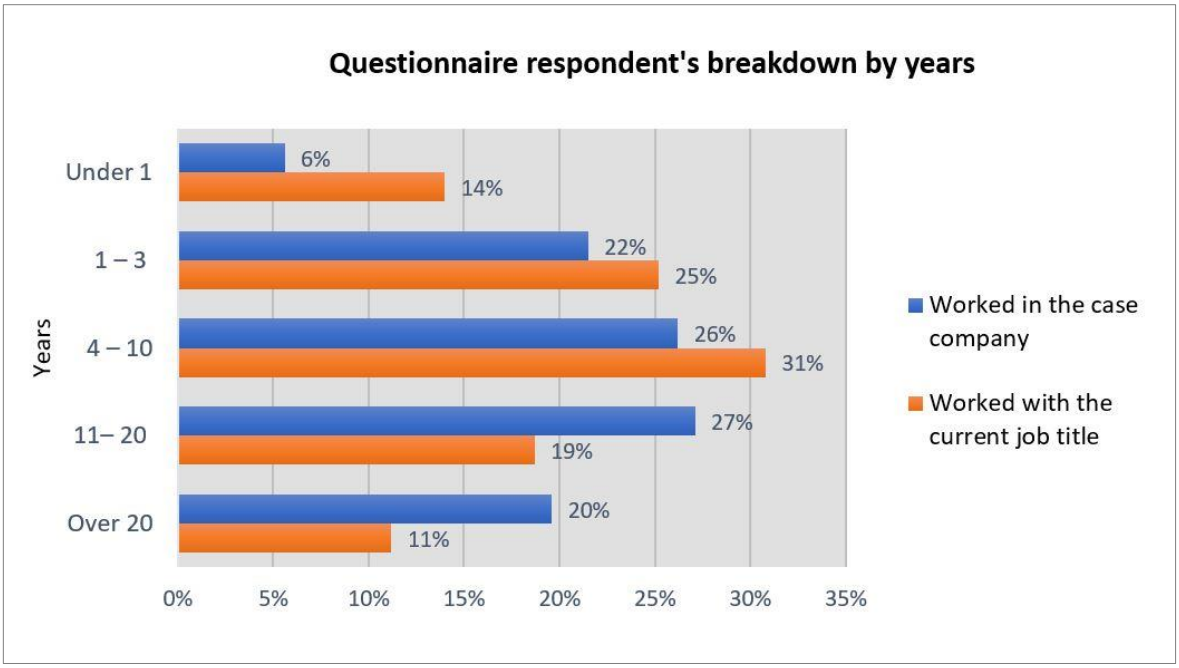

Figure 20. Questionnaire respondent's breakdown by years worked in the case company and worked with the current job title.

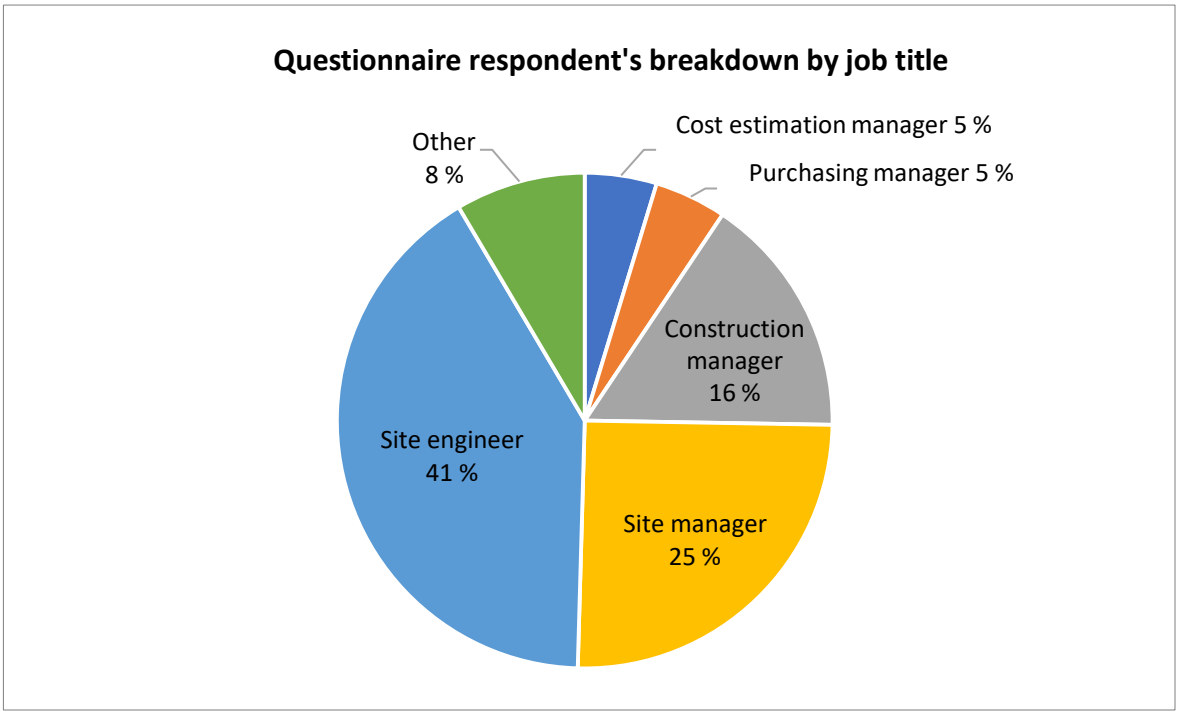

Figure 21. Questionnaire respondent's breakdown by job title.

3.2 Risk management guidelines and R&M-analysis tool

3.2.1 Risk management guidelines

The case company has an operating system that covers the core functions of the company. An operating system is a written way of working in a company (Case company, Document 3: TJK Koulutusohjelma, 2019). The activity system consists of a company, unit, and project-specific entities. The business system is applied to the project business of the company, which includes bidding activity, design control, procurement, and production-related support functions. (Case company, Operating system, 2020.)

The activity system is in Pro3-platform, which is a tool for monitoring and managing projects and processes developed by Derigo (Derigo, 2020). Pro3 also includes a tool, threat and opportunities analysis (riski- ja mahdollisuusanalyysi) for risk management. Threat and opportunities analysis tool is often abbreviated as 'R&M-analysis tool', and also this thesis uses the latter expression. In the operating system of the case company, risk management is described as follows (translated, Case company, Document 1: Risk analysis, Operating system, 2017):

> *The purpose of threat and opportunity analysis is to minimise the likelihood and consequences of an undesirable event. When dealing with opportunities, the purpose is the opposite: to maximise the likelihood and positive consequence of the event.*
>
> *R&M-analysis is about getting the project's threats and opportunities under control, which in turn reduces the number of loss-making projects. Well planned treatments minimise the occurrence and consequences of threats and maximise opportunities.*

R&M-analysis helps us make considered and justified choices, prioritise, and identify appropriate practices. The system will increase our knowledge of threats and opportunities, which in turn will help us understand past events and improve our way of working in the future.

Threat and opportunity analysis is done with the Pro3 tool. The same tool is used throughout the project from the tender phase to the construction phase. Treats and opportunities identified during the determination of the tender are included in the tender price. As the production phase begins, the threats and opportunities left in the R&M-analysis tool are reassessed, and the threats and opportunities identified by the production are added. As construction progresses, analysis is regularly updated, and values of risks are used as a tool for a project's economic forecasts.

The following Figure 22 is attached to the description above. It represents the risk assessment and treatment process defined by the case company.

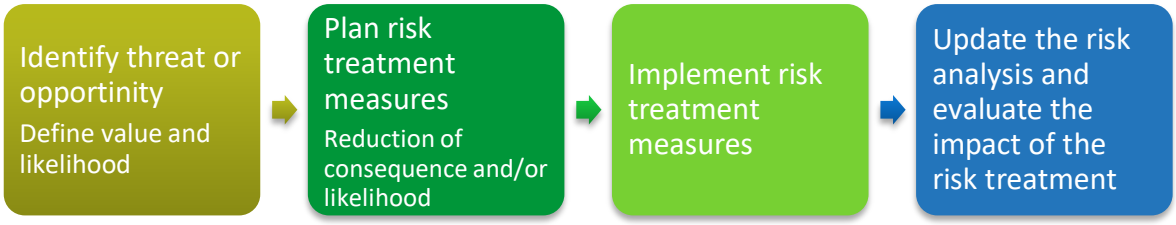

Figure 22. Risk management process of the case company (translated, Case company, Document 1: Risk analysis, Operating system, 2017).

The description in the operating system is accompanied by more detailed instructions (Document 2) to the use of the R&M-analysis tool itself. These instructions are named as 'Riski- ja Mahdollisuusanalyysi – Pro3 työkalu'. Next, these instructions are introduced.

At the beginning of the instructions, the role of risk management in projects is dealt with more detailed. There is overlapping with the description of the operating system about risk management. As new information, instructions have the following texts (translated, Case company, Document 2: Riski- ja Mahdollisuusanalyysi – Pro3 työkalu, 2017):

Risk management is an integral part of NCC's operations. Project risk management measures and practices can be found in Pro3. There is also, among other things, NCC's decision-making guidelines and, for example, assessment of occupational safety risks.

By using and following the agreed course of action, NCC's risk management is actively improved. The agreed procedures also ensure that risk management is an integral part of the routine and daily operations of different construction projects.

A systematic course of risk management action is created by establishing common concepts, processes, and tools.

Coherent course of action forms a consistent risk management culture within NCC.

The R&M-analysis begins at the sales stage and is constantly updated throughout the construction process. The R&M-analysis is gone through at the decision-making points.

Then these decision-making points are presented and supported with the process description presented in Figure 23. In addition to these four points, instructions mention two decision-making points that happen at the end of the construction phase. These are approval of the finishing program and the final financial statement. Then the instructions continue with detailed instructions of the use of the tool. Next subchapter introduces the R&M-analysis tool based on these instructions.

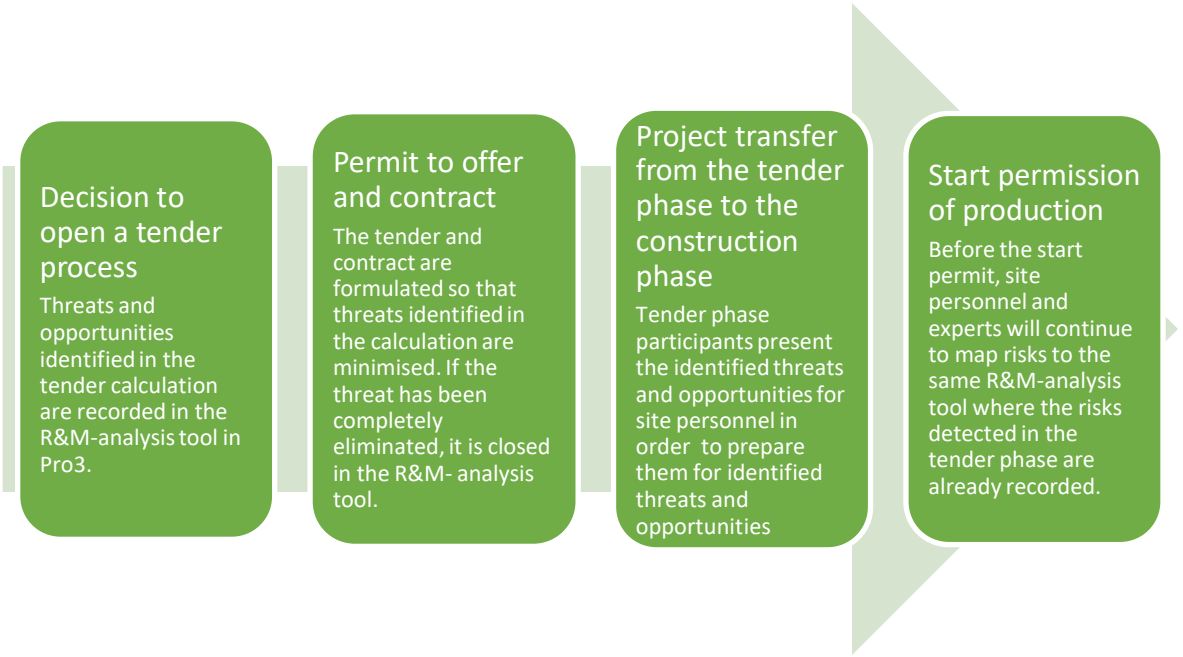

Figure 23. The risk management process in the decision-making point of view (translated, Case company, Document 2: Riski- ja Mahdollisuusanalyysi – Pro3 työkalu, 2017).

3.2.2 R&M-analysis tool

This subchapter describes the risk management process of the case company in the R&M-analysis tool point of view. Subchapter is divided into four sections based on the process stages. These stages were presented on the previous page in Figure 22.

Identify threat or opportunity

Risk management process defined by the case company starts with risk identification. Instructions urge following (translated, Case company, Document 2: Riski- ja Mahdollisuusanalyysi – Pro3 työkalu, 2017):

Identify risks from the client, contract form, contract terms, special characteristics of the project, the difficulty of the implementation, occupational safety, environmental impact, assessment of cost level change, and from organisation's competence. Make the identification together with different areas of expertise or experts.

Instructions have a list of aspects to be considered to support risk identification. These include risks related to contract & clients, planning & plans, quality, schedule, technical implementation, economy, safety, surroundings, human resources, and the brand of the company. The R&M-analysis tool has a very comprehensive list of pre-identified risks, and instructions tell how to use these pre-identified risks. When threat or opportunity is identified, it is recorded into R&M-analysis tool. Furthermore, the instructions guide where one can find the tool. The window for adding new risk to the tool is presented in Figure 24.

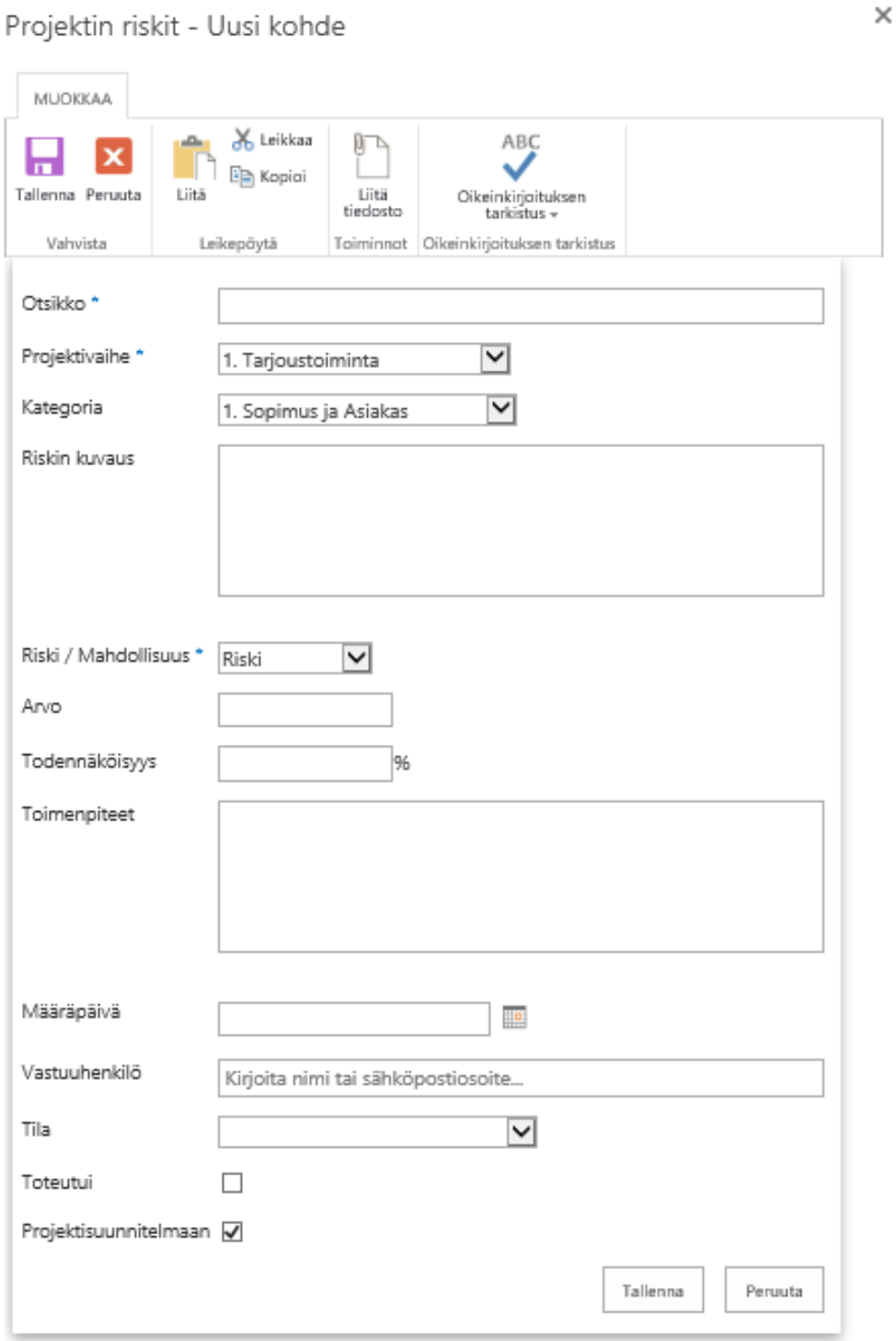

Figure 24. The window for adding new risk to the R&M-analysis tool (Case company, Operating system, 2020).

The first step is to fill is ‘title’ (otsikko). In practice, the title means the name of the risk. The next step is to choose ‘project phase’ (projektivaihe) from the drop-down menu. One can select from six different options listed below:

1. Tender activity (tarjoustoiminta)
2. Planning (suunnittelu)
3. Preparation for construction (rakentamisen valmistelu)
4. Construction (tuotanto)
5. Finishing and commissioning (viimeistely ja käyttöönotto)
6. Operation and maintenance (käyttö ja ylläpito).

Then, the ‘category’ (kategoria) of risk can be choosed from options listed below:

1. Contract and customer (sopimus ja asiakas)
2. Planning and plans (suunnittelu ja suunnitelmat)
3. Quality (laatu)
4. Schedule (aikataulu)
5. Technical implementation (tekninen toteutus)
6. Procurements (hankinnat)
7. Economic (talous)
8. Occupational safety (työturvallisuus)
9. Environment (ympäristö)
10. Human resources (henkilöstöresurssit)
11. The brand of NCC (NCC:n brändi).

Then, the tool offers a field for the ‘description of risk’ (riskin kuvaus). Next, one can choose if the risk is ‘threat’ (riski) or ‘opportunity’ (mahdollisuus). Then the ‘value’ (arvo), or in other words, consequences of the realised risk in euros and ‘likelihood’ (todennäköisyys) of the risk occurrence in percentage should be estimated. Instructions recommend that one should make use of experts from different disciplines to assess the value and likelihood of a risk. Instructions also suggest calculating the consequences of risk and save the calculation so that it can be viewed as the project progresses. The tool calculates the level of risk automatically. The calculation is done based on the definition of risk so that the consequences are multiplied with the likelihood. The rest of the steps are not mandatory and can be left blank. Instructions urge that risks should also be prioritised so that key threats or opportunities are addressed first.

Plan risk treatment measures

Then, the project organisation should define and plan its measures for ‘risk treatment’ (toimenpiteet). Instructions urge to design treatments to either avoid or reduce threats. The given treatment strategies and examples are as presented in Table 9. After the measure is chosen, ‘due date’ (määräpäivä) and ‘responsible person’ (vastuuhenkilö) should be defined. Instructions tell that the system will automatically send an e-mail to the person in charge.

Table 9. Treatment strategies and their examples (translated and compiled from Case company, Document 2: Riski- ja Mahdollisuusanalyysi – Pro3 työkalu, 2017).

Treatment strategy	An example	Treatment measure
Avoidance: Planned action that involves the threat is not implemented. It also results in potential benefits being lost.	One of four subcontractors offers a remarkably low bid. A company is considerably smaller than others, even in terms of resources. There is a threat of bankruptcy and the possibility that the job will not be completed.	Avoiding the threat means that the tender of the subcontractor will not be accepted. This will, therefore, result in additional costs.
Reduction: Reduce the likelihood of a threat realisation and/or a deterioration in performance.	A broken hollow-core slab field has been designed for the site, which poses safety and quality risks.	Change the floor structure to be completely in-site casted.
Sharing: Transferring threat, in whole or in part, to suppliers or subcontractors. NOTE: NCC retains the customer's responsibility for the action and threat!	Risky and challenging foundation.	The risk is shared by selecting a competent partner with whom the implementation method and price are planned and agreed upon.
Retention: The action is taken despite the potential impact of the threat.	One of four subcontractors offers a remarkably low bid. A company is considerably smaller than others, even in terms of resources. There is a threat of bankruptcy and the possibility that the job will not be completed.	The threat is accepted, and the lower offer is accepted. NOTE: Risk monitoring as the project progresses.

Implement risk treatment measures

Then instructions urge to make a more detailed task plan based on risk. The responsible person implements the measures and monitors their success. The treatment must result in changed consequences or likelihood.

Update the risk analysis and evaluate the impact of the risk treatment

After risk treatment measures are implemented, the new value and likelihood are recorded. This is followed by a revised risk assessment to ensure that an acceptable level of risk is achieved. Depending on the effectiveness of the treatment, it may need to be reviewed and modified during the project. Risk status should be determined as the project progresses. One can choose from four following alternatives:

1. Risk identified (riski tunnistettu)
2. Treatment decided (toimenpide päätetty)

3. Treatment implemented (toimenpide toteutettu)
4. Risk excluded [The level of risk 0] (Riski pois suljettu [Riskitaso 0]).

Finally, instructions remind that regardless of the effectiveness and success of the treatment, the identified threat or opportunity must never be closed until it has been passed in the project. Only then can the success of the operation be determined with certainty. If the probability is 0 %, the risk is closed. Instructions also note that R&M-analysis tool is also a tool for forecasting the economy of the project. The last steps are to mark if the risk has 'realised' (toteutui) and if it has been imported 'to the project plan' (projektisuunnitelmaan).

When risks are recorded to the tool, the front page looks as presented in Figure 25. Columns in the header row (marked with a red rectangle) from left to right translated to English are: ID, title, project phase, category, description of the risk, value, likelihood, level of risk, risk treatment, due date, responsible person, status, to the project plan and realised. The tool also calculates the overall risk level of the project by summing up the level of threats and opportunities (marked with a blue rectangle).

Figure 25. The risk listing of a project in R&M-analysis tool (Case company, Operating system, 2020).

3.3 Risk management operations in projects

3.3.1 Risk management generally

At the beginning of the interviews, after general information of the interviewees were obtained, questions aimed to find out the general perception of risk management, its importance, and benefits achieved through it. Most of the interviewees defined risk management as divination or prevention of negative events that project may be facing. Risk management was considered as an action that takes into account the special features of the project. Several interviewees brought out that risk management is more than just filling out the R&M-analysis tool. Also, several interviewees (7/25) brought out by themselves that risk management should consider, in addition to threats, also opportunities.

> *It [risk management] means that you take note of everything that could go wrong in order to be able to finish the project as desired (Interview 2).*
>
> *Risk management means taking into account the special features of the project that they can be prepared for, as well as the threats but also the opportunities. Risk management plays a huge role in the management of the project, and then, some individual tool does not respond to it, but all the work done in the project is a kind of risk management. (Interview 3.)*
>
> *I think risk management includes all the risks related to your work task, the financial, time, quality, and safety risks. But risk management is not just about threats, because there is always the opportunity; these two always go hand in hand. So, you should also think about where you can succeed. (Interview 15.)*

The questionnaire revealed that 94 % of the 107 respondents considered risk management to be ‘very important’ or ‘important’ in project management. The average grade for the importance in the 1 to 5 scale, where number 1 represents ‘unimportant’ and number 5 represents ‘very important’ was 4.55. Furthermore, all interviewees considered risk management as an essential part of project management.

> *Risk management is the foundation for project management (Interview 16).*
>
> *Can there be project management without risk management as one part of it? – – Otherwise, project management is based on luck. (Interview 19.)*
>
> *It [risk management] is probably one of the things that determine the success of the project – – it is really relevant part (Interview 23).*

When interviewees were asked about the benefits achieved through risk management, answers included certainty for the project and smoother project progress. Also, risk management was considered as a help in completing the project as planned. One interviewee highlighted that risk management raises the accuracy of the project's economic forecasts (Interview 5). Generally, risk management was considered as a beneficial part of project management, not just ‘a must-do’.

> *When we anticipate, we also plan our tasks better, and then we are more likely to achieve the desired end-result (Interview 2).*
>
> *Risk management provides certainty for the project at all levels; schedule, occupational safety, environmental issues, and financial aspects (Interview 3).*
>
> *Usually, when threats are identified, they will not realise (Interview 10).*

The fact that we go through possible threats and talk about them has been reflected so that the level of occupational safety has risen. If we can raise the safety level even more to very high, it also reflects the good mood to the site. Furthermore, it will be seen as an urge to try the best one can, which can be seen as a positive outcome in the timing and quality. (Interview 15.)

Most of the interviewees (16/18) saw that risk management is most important at the beginning of the project in the tender phase. It was justified, for example, by the fact that decisions made before submission of the tender have the most significant economic impact. This result is in line with the literature review. Decisions with the most significant impact are made in the early phases of the projects.

It is essential that you recognise the biggest threats already in the tender phase. There might be a decision that you do not even do a tender. (Interview 6.)

[Risk management is most important] at the beginning of the project, when you can still affect the plans (Interview 7).

As early as you identify threats, the cheaper it is to prevent them (Interview 9).

Among interviews where the subject was talked about, two answers (2/18) differed from the majority opinion. One interviewee answered that risk management is most important at the time when a new task is starting (Interview 4). The other interviewee thought that risks are so different, that certain risks are more relevant in one phase and particular in others. Thus, there is not one single phase when risk management is the most important. (Interview 23.)

3.3.2 Risk management practises in projects

This section aims to give an in-depth depiction of the risk management practises in construction projects. Risk management happens at various level in the project. Several (7/25) interviewees highlighted the importance of daily activity in project risk management by themselves. However, due to the scoping of this thesis, research focuses on regular, project-wide risk management that is recorded to the company's risk register (R&M-analysis tool).

The project risk management process in construction can be divided into three stages: 1) tender phase, 2) construction phase, and 3) warranty phase. In risk management point of view, the tender phase starts from the very beginning of the project and ends at the time the tender is submitted. Then, the construction phase starts and lasts until the project is handed over to the client. From that point, the project is in the warranty phase until its warranty period is over. The risk assessment process itself should be the same in every phase. However, the framework of the process can vary depending on the phase. Aspects that are varying are, for example, identification methods, people involved, and frequency of the risk management meetings where risks are assessed together. However, the thesis is limited to focus on the tender and construction phase. Thus, the description of the process is divided into two sections: the tender phase and the construction phase. The questionnaire had a question about phase the respondents feels to work mainly. Among 107 questionnaire respondents, 74 % answered that they work in the construction phase, 5 % at the tender phase, and 18 % that they work at both phases. 3% of the respondents answered that they

work neither of the phases but in after-sales or procurement of year agreements. Next, risk management practises are described chronologically.

The tender phase

Project risk management starts from the very beginning of the project when the tender phase starts. According to interviews, the first aspects to think are what are the company's areas of expertise and through that think what kind of project it should participate (Interview 18). At the beginning of the tender phase, the focus is on economic risks. Next, questions that are in consideration are, for example: 'Do we have human resources?', 'Is the location suitable for us?' and 'Is the timing good?' (Interview 16). If these aspects are favourable, and the decision is to start to calculate the tender, the tender organisation starts to map the risks as they familiarise themselves with the project. (Interview 18.)

Both interviews and questionnaire revealed that the risk management process and practices vary in the tender phase. Among questionnaire respondents who participate in the project at its tender phase (28 respondents), 64 % told they have regular meetings for risk management, 22 % told they do not have, and 14 % could not answer.

Among questionnaire respondents who told they have regular meetings, the questionnaire asked to assess the attendance of different job titles to risk management meetings in the tender phase. The response options were: 'always or almost always', 'sometimes', 'never', 'do not attend, but gives comments', and 'NA'. The job titles that participate most often were (percentage of respondents that answered the category 'always or almost always' is marked after the job title):

- construction manager (100 %)
- project manager (81 %)
- cost estimation engineer (83 %)
- cost estimation manager (59 %)
- operations manager (56 %)
- head of production (55 %).

Job titles, who were mostly told to attend sometimes were percentage of respondents that answered the category 'sometimes' is marked after the job title):

- purchasing manager (81 %)
- purchaser (67 %)
- regional manager (61 %)
- quality and environment manager (43 %, also 43 % told they do not attend)
- safety manager (43%, also 43 % told they do not attend).

Answer distribution related to HVAC-specialists and law department vary evenly among answers 'always or almost always', 'sometimes', and 'do not attend but gives comments'. Both interviews and questionnaire revealed that site manager, site engineer, and foreman do attend if they are already named to the project. Participations are determined based on the project's size and complexity, so that smaller, basic projects have fewer participants and more extensive and complex projects more participants (Questionnaire, open response option).

According to the questionnaire, risk management meetings are mainly held irregularly a few times during the tender phase. Figure 26 represents the distribution of answers.

Figure 26. The frequency of risk management meetings during the tender phase (by the questionnaire, n=18).

If 'formal' risk management meetings are not held, the way to do risk management varies among the projects. The first commonly used model is that risk assessment is done together, but not in separate risk meeting. Risk assessment is involved in every meeting of the tender phase. These meetings are, for example, start-up meeting (aloituspalaveri), procurement meeting (hankintapalaveri), and tender meeting (tarjouspalaveri). (Questionnaire, open response option.)

A model in which the construction manager has the major responsibility of risk management is also in use. The construction manager prepares the risk analysis based on his or her own experience and expertise. Then he or she may get comments from other stakeholders of the tender process such as from law or procurement department. Risk analysis can also be checked together in the tender meeting.

> *The construction manager prepares the risk analysis. The analysis usually consists of the manager's view of the project's risks, the comments of the law department and the views of other personnel involved in the tender calculation. How and which risks are priced and what is the overall risk level of the project – – are evaluated in the tender meetings. With this decision, the department nails its own opinion on the risk of the project. (Questionnaire, open response option.)*
>
> *I do not know if we have a meeting for that [risk management]. I do it [R&M-analysis] always with my computer, and then we go it through in tender meeting. Furthermore, our manager [operational manager] wants to see it. (Interview 9.)*

One of the interviewees told that the R&M-analysis is done solely by the construction manager, and nobody gives comments. The interviewee was concerned about the lack of opponency and support.

It [risk analysis] is my tool for the tender preparation, so I wish I would get a little support. Now nobody is interested in what I wrote on that and what was done for them [identified risks]. (Interview 1.)

The construction phase

Among questionnaire respondents who participate in the project at its construction phase (n=102), 54 % (55 respondents) told they have regular meetings for risk management, 35 % told they do not have, and 11 % could not answer. Other respondents than who could not answer, were directed to choose the most suitable answer to describe how risk management is done in their projects. Answers are presented in Figure 27.

Figure 27. Risk management practises in projects (by the questionnaire, n=91, the first option was chosen by 51 respondents).

Results correspond with to each other; 55 respondents told they have regular meetings for risk management and 51 respondents told that risk assessment is done as teamwork. Next, risk management meetings are concerned.

Questionnaire respondents who answered that they have regular meetings for risk management were asked to choose a suitable description for their meeting. Options were created based on the data achieved from the interviews. As can be seen from the results, which are presented in Figure 28, answers vary among the respondents. Most popular descriptions for risk management meeting were that risks are assessed in separate risk management meeting or monthly in the construction manager's follow-up meeting (työpäällikön seurantapalaveri), and the tool is filled during the meeting. In addition to these, it came up that risks may be concerned regularly in the weekly meeting (viikkopalaveri) of the site. According to the interviews, recording of the operation to the R&M-analysis tool is usually done by the site engineer. Attitude towards recording is of unfortunately often that it is done so that the system does not revile.

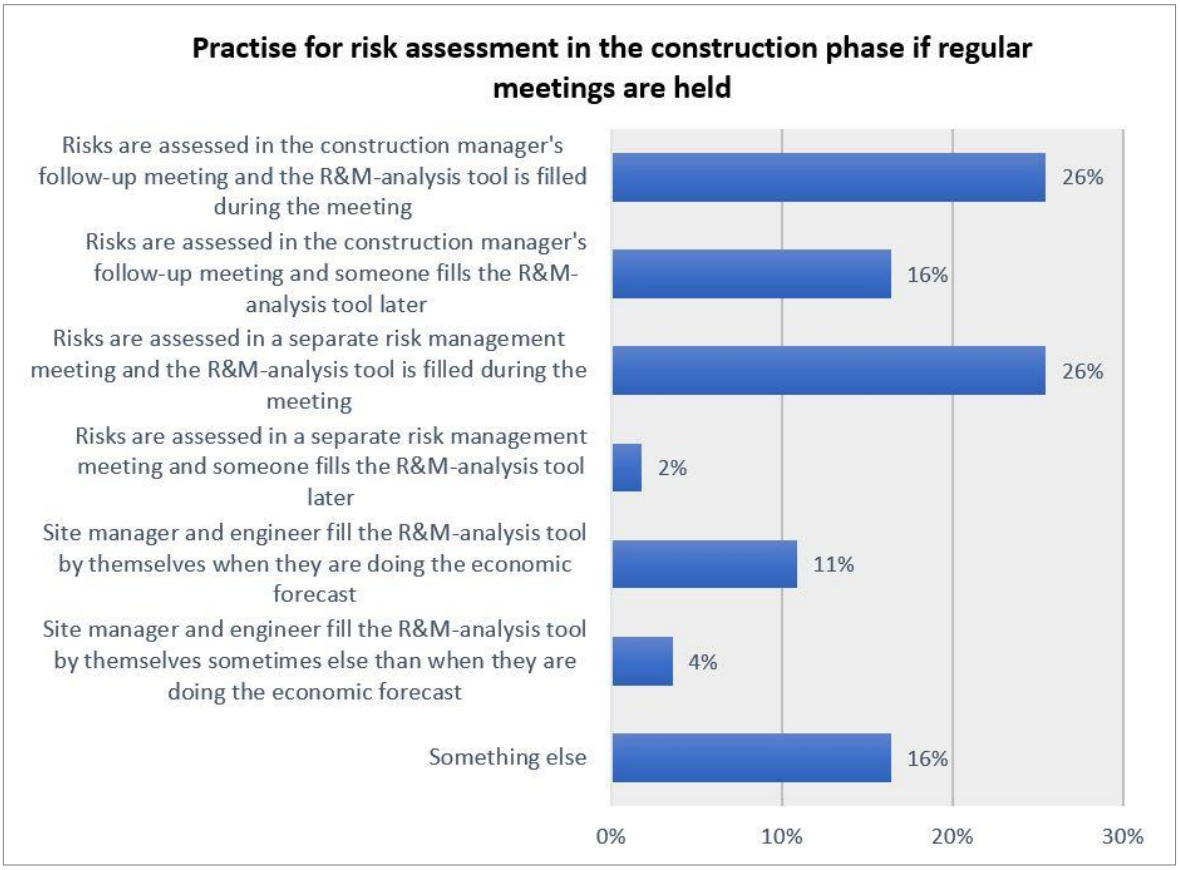

Figure 28. Practise for risk assessment in the construction phase if regular meetings are held (by the questionnaire, n=55).

The frequency of meetings was asked among respondents who told they have regular meetings. Answers are presented in Figure 29.

Figure 29. Frequency of risk management meetings in the construction phase (by the questionnaire, n=55).

According to interviews, the R&M-analysis tool reminds the construction manager if the tool is not updated once in a month. From the answers of the questionnaire can be deduced that if only half of the respondents consider that risk management meetings are held once in a month, part of the updates is done by one person or by one person with the support of others. Furthermore, this reveals that risks are not collaboratively assessed monthly.

The questionnaire also concerned who is participating in risk management in the construction phase. Figure 30 represents the results.

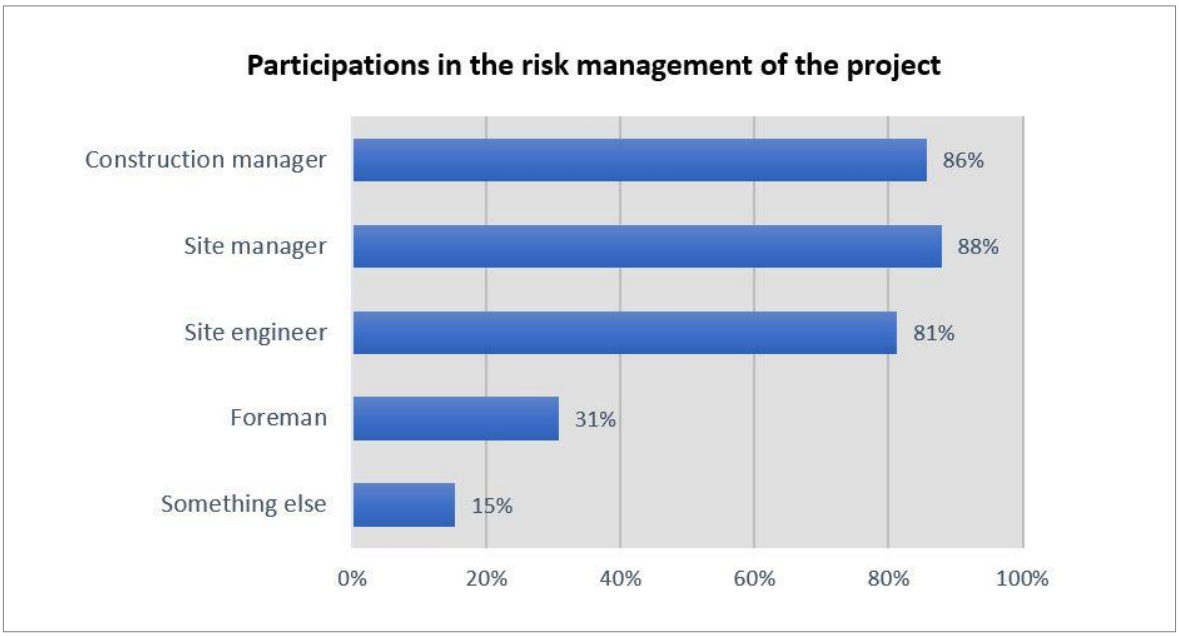

Figure 30. Participations of the risk management of the project (by the questionnaire, n=102).

In the questionnaire, there was also a separate question about the attendance of foremen in the risk management meeting. Among 54 respondents, answers were as follows: 20 % chose the option 'always or almost always', 16 % chose 'most of the time', 47 % chose 'irregularly', and finally, the option 'never' was chosen by 16 % of the respondents.

According to interviews, after-sales have participated in risk management during the construction phase if needed. As examples, they have attended to plan review meetings (suunnitelmakatselmus) and a moisture management specialist has been asked for a consultation on how a specific roof structure should be implemented. The after-sales managers of one department told that the interest of production personnel about realised threats in the warranty phase has raised. They told that the pursuit and desire not to have so many problems in the warranty phase has grown among employees in the construction phase. (Interviews 12 & 13.)

The level of risk management

Because the level of risk management is not in the research questions, this subject was only briefly concerned in the research. In questionnaire was questioned "What is the level of risk management in your ongoing or most recent project?" in order to find out the level of project risk management in the case company from the employees' point of view. The average grade in 1 (very poor) to 5 (very good) scale was 3.63. The distribution of answers is presented in Figure 31.

Figure 31. The level of project risk management (by the questionnaire, n=107).

There was no direct question about the level of project risk management in the interviews. However, part of the interviewees brought out the subject by themselves. A couple of interviewees (2/25) told that the level of risk management differs among the projects (Interviews 2 & 16). The problem is that risks are assessed in the tender phase and then at the beginning of the construction phase, however later, during the construction phase, the activity is faded, and new risks are not identified (Interview 2). Interviews brought out that risk management is strongly related to personnel working on the projects. One interviewee described the subject as follows:

> *This is more related to people than a division or company. – – It is the people who are in or deals with that project that determines its level [of risk management]. (Interview 23.)*

Furthermore, many (7/25) of the interviewees brought out by themselves that risk management has improved a lot in the past few years. Next subchapter concerns the components of the risk management process starting from the risk identification.

3.3.3 Risk identification

Risk assessment starts with risk identification. One section of the questionnaire aimed to find out how easy or difficult it is for respondents to identify threats and opportunities? Questions were: "How difficult or easy do you consider identification of threat?" and "How difficult or easy do you consider identification of opportunity?" As can be seen in Figure 32, the identification of opportunity was concerned to be more difficult than the identification of threat.

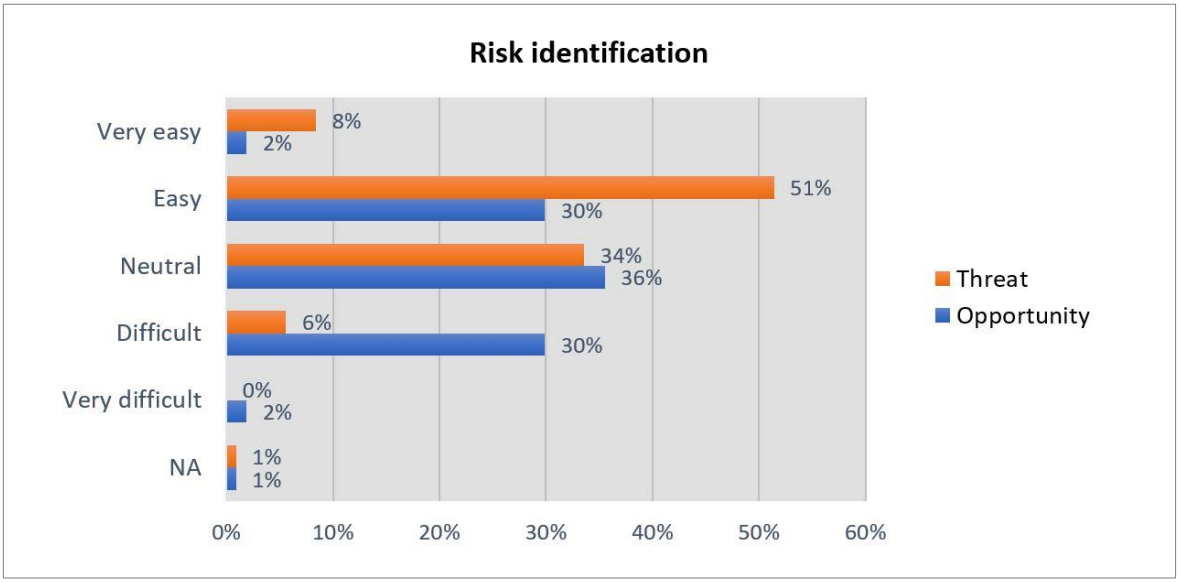

Figure 32. The difficulty of threat and opportunity identification (by the questionnaire, n=107).

In interviews, the question related to risk identification was: "How risks are identified?" The question aimed to find out how interviewees identify risks, and do they use tools for risk identification. The collective opinion of the interviewees was that risks are identified with experience and expertise. Risk identification was described as follows:

> *[Risk identification is made with] professionalism, that comes from experiences. We use knowledge related to previous projects, stakeholders, project delivery methods, and contracts. (Interview 21.)*

> *Challenge is that it [risk] is not certain concrete thing in that [identification] moment. It is something that you can see, and you are able to visualise. You can see what things could lead to each other. You are viewing the client, contractor field, and market conditions. You have been reading documents of the project. You must combine these things in order to identify risks. (Interview 19.)*

In the tender phase, risk identification is made by reading various documents. Interview respondents brought out, for example, commercial documents such as terms and conditions, work specifications, and existing plans. A couple of interviewees determined that three types of risks that should be identified are risk related to contract specifications, technical risks, and schedule risks (Interviews 9 & 17).

> *There are so many different risks and ways to identify them. – – However, money is maybe the determining factor, or time, but time is usually money for us. – – We think about the most important and biggest risks in terms of money, and the most important and biggest things that may have effects on schedule. (Interview 17.)*

In the construction phase, risks are identified by multiple ways. Risks related to time can be identified from the schedule. The tracking vignette (seurantavinjentti) can help to deduce these risks. From the economy point of view, transcript cards (litterakortit) are a vital tool. When the project organisation is identifying safety risks, they can use safety observations (työturvallisuushavainnot) or report from occupational safety inspections (TR-mittaukset). Identification of quality threats was described as follows:

> *In a project, we know that when we run out of time, next, we will run out of money, and then we start to lose quality. – – But often, it is possible to see how quality targets will be achieved just by looking at the schedule. (Interview 15.)*

Generally, interviewees highlighted the value of teamwork. Also, self-motivated thinking and activity were considered as beneficial features for risk identification. One interviewee emphasised the importance of the construction manager's experience (Interview 6).

> *It [risk identification] is the kind of teamwork, where we go things through together, and everyone attended can say what kind of risk they identify (Interview 10).*

> *In my opinion, at its most genuine, it [risk identification] comes from self-motivated activity (Interview 18).*

The R&M-analysis tool offers a list of pre-identified risks. The usage and opinions about pre-identified risks vary among interviewees. Also, the questionnaire respondents have highly dispersed answers. Among respondents who reported that they have been using the R&M-analysis tool (65 respondents) the most popular answer (51 %) was that the list has sometimes been used as a help, but not regularly. 12 % answered that they continually use risk list for risk identification. Furthermore, 12 % answered that they do not use the list, but are aware of its existence. The rest (25 %), did not use the list and did not even know about the existence of it.

In the interviews, only one told that the list of pre-identified risks is in use for risk identification in the tender phase (Interview 1). However, interviews revealed that individual people and teams had created their own checklists for risk identification. It happens in both, the tender and construction phase.

> *In the tender phase, I do not start from scratch. I take the risk list, and from there, I pick up which risks this project may be facing. Then I move them into analysis and write down what they mean in this particular project. At that point, I have read the contract and commercial documents. – – [When asked about risks that are not in the list of pre-identified risks.] The risk list is so comprehensive that I have never identified a risk that could not be found in the list. (Interview 1.)*

> *There is no official list, but we have done client-specific checklists for our own use (Interview 3).*

In the construction phase, the usage of pre-identified risk listings varied among interviewees. Interviewees who used these listings had the following opinions:

> *Yes, we use risk list and then our own reasoning (Interview 16).*
>
> *It is terribly difficult for people [to identify risks] because of the fear of blank paper. It [list of pre-identified risks] is there, on the background – – and it can be brought for the project, and it also assists with risk identification and wakes up our thinking. (Interview 2.)*
>
> *I have used it [the list of pre-identified risks], but it is quite long. There is a lot of unnecessary risks and funny headers. (Interview 9.)*

However, various respondents brought out the negative side of the use of pre-identified risks. When the list is used as the only tool for risk identification, there is a danger that some risks remain unidentified. Also, the listing was seen as limiting one's own thinking. One interviewee would like to have some marking if the risk is identified directly from the listing. If the identified risks are only those pre-identified risks, there may be a danger that no one has considered if there could be risks from outside of the list. Also, the need for updating the list of pre-identified risks was mentioned. (Interview 19.)

> *When you follow the pre-identified risk listings, there is a danger of some real risks remain unidentified. Thus, I prefer teamwork, experience, and expertise. (Interview 10.)*
>
> *The use of listing is not necessarily good even though risks can be modified. When risks are given, one's own thinking may disappear. Basically, you can make the risk identification for a particular project just by picking risks from those pre-identified risks. (Interview 2.)*

One interviewee was concerned about the effect of the project organisation because the same risk can be a risk for one team and not for another (Interview 10). Another interviewee was worried about people not knowing what risk is, and thus some risk types are forgotten. According to the interviewee, risks related, for example, to sustainable development are not dealt with enough. (Interview 2.) When interviewee was asked about other risk types that are forgotten, the answer was as follows:

> *We should always consider when we have a client whom we have not built before. Also, we should consider risks always when someone or something changes. There is often risk analysis where the project is not risky because they have done it before. Also, skill gaps of employees are not always seen as a risk. (Interview 2.)*

3.3.4 Risk analysis

In the project risk management process of the case company, risks are analysed according to the value of the consequences if the risk realises and the likelihood of risk realisation. Value is the numerical estimation in euros and likelihood in percentage. The questionnaire aimed to find out the difficulty of the risk analysis in numerical terms. The results are presented in Figure 33.

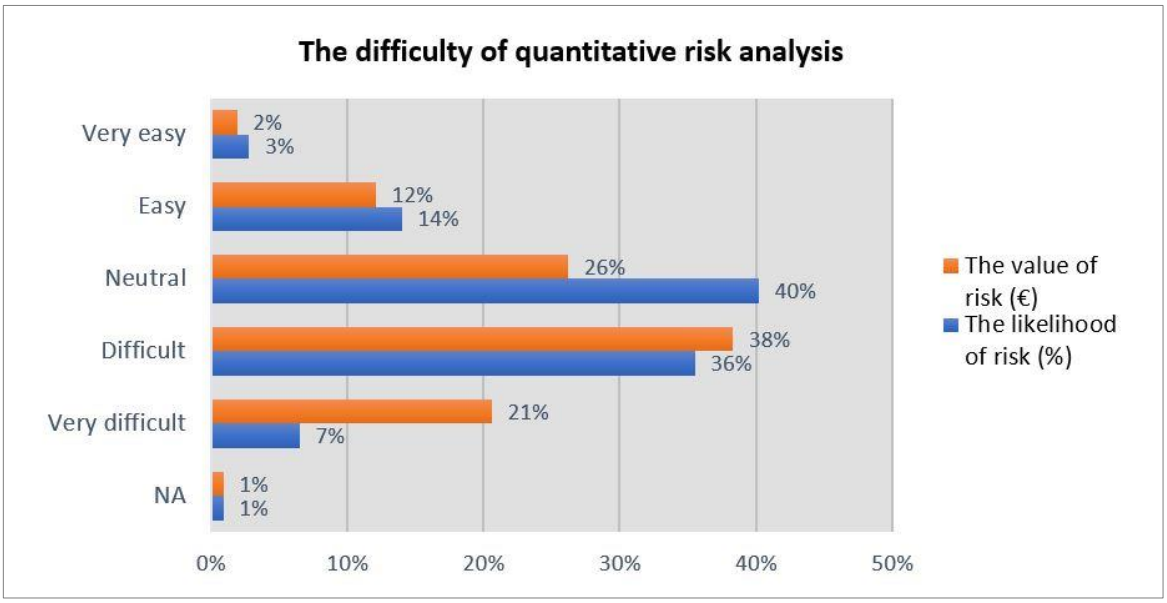

Figure 33. The difficulty of quantitative risk analysis (by the questionnaire, n=107).

When compared to other components of the risk management process, quantitative risk analysis was considered as the most challenging task of the process. The average grade of the difficulty of each component is presented in Figure 34.

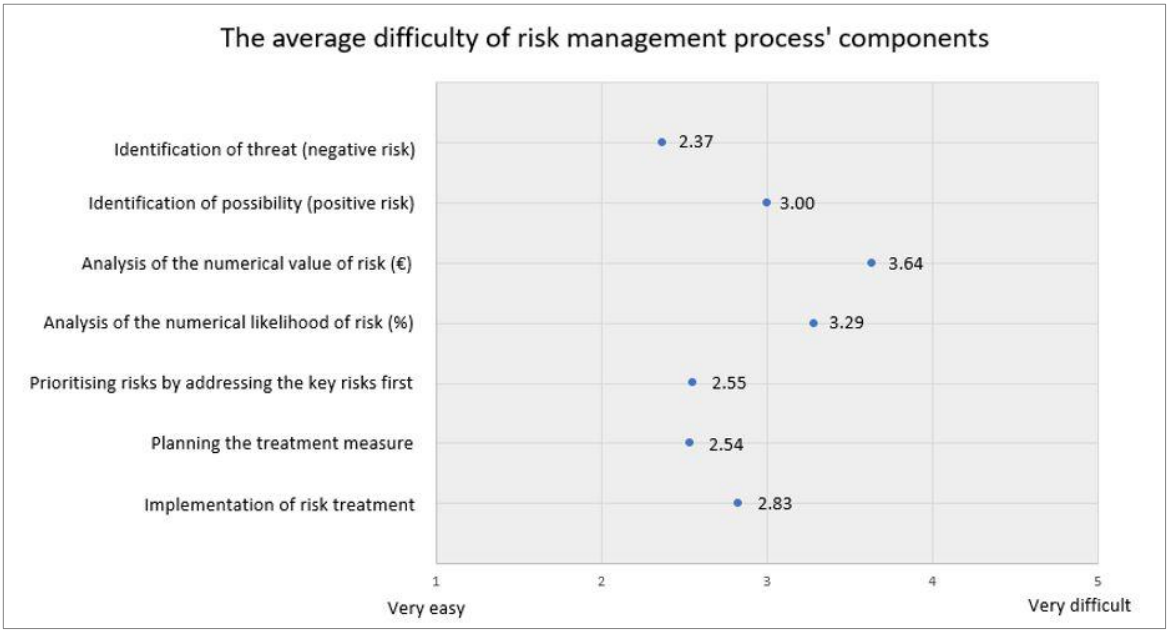

Figure 34. The average difficulty of the risk management process' components (by the questionnaire, n=107).

Interviewees, without exception, thought that quantitative risk analysis method is complicated. Respondents told that when they are doing the risk analysis, they try to give their best estimation. Also, own experience and colleague may be helpful.

> *That is a guess. – – There are as many results as there are doers. Nowhere has anyone ever been able to tell how risk should be analysed; which value to put and what the likelihood is. No one taught it, but one must think about how to do it by themselves. (Interview 1.)*
>
> *Only in some rare risk, we can say what is the exact value in euros and even then, the percentage is an estimation (Interview 19).*
>
> *If we talk about, for example, material choices, it is easy; it is a difference in the price of a square meter. Furthermore, if we talk about things which have direct procurement costs or damages. – – What if we change production technology or frame structure? – – How can you compare them in money when these structures function in a completely different way? (Interview 20).*

Risk analysis in numerical terms is a doable way to compare risk that has a direct cost effect on the project. However, as the last quote brought out, there are risk types whose quantitative analysis can be difficult or even impossible in the project level. Thus, this analysis method may be an unnecessarily narrow approach. According to interviewees, risks that often do not have direct cost effects to a project are, for example, environmental risk, safety risk, and the risk of damaging the company's brand. Also, client risk, for example, if the client is extremely demanding, was mentioned as a risk that may be difficult to analyse in quantitatively.

> *There can be other than the direct financial loss to the project; for example, our reputation goes down, which causes indirect costs. However, we cannot give any value for the threat in an individual project. (Interview 2.)*

In these cases, interviewees told that they try to scale the risk or put risks in rough order of magnitude. Also, some left these without numerical values.

> *We try to scale their magnitude, so that if a thing 'a' is 100 k€ and thing 'b' is much less significant, so it can be for example 20 k€. So, these risks are compared to each other. – – Values depends very much on how big the project is. Even though the consequences of risk in euros are not big in a small project, it can be significant in percentage to that one project. (Interview 4.)*
>
> *I just put some equal values to likelihood, such as 25 %, 50 %, or 75 % (Interview 7).*
>
> *We do not price them [threat of personal injury or imago] – – If there is a threat of personal injury, then no tender will be made. (Interview 8.)*
>
> *Then [when risk is hard to analyse qualitatively] you must find treatments to completely block that risk so that the realisation is not possible (Interview 18).*

Furthermore, there are also conflicts between risk analysis and cost management of the project. The total sum of risk level should be approximately the same in R&M-analysis tool and risk letter (riskilittera) of the cost management system. Nevertheless, if there is a risk that does not have direct consequences in the project level, the sum in R&M-analysis and in cost estimation of a project cannot possibly be the same. (Interview 7.)

The level of risk is calculated so that the consequences are multiplied with the likelihood. Interviews came up to that this method can be an ambiguous way to determine the risk level. Next, to clarify the observation, the following example is presented: Project may be facing the threat that windows need to be replaced. There is a 50 % likelihood that the threat realises, and it will cost 100 k€. So, the risk level is 50 k€. However, if the risk realises, one must replace all the windows, and it will cost 100 k€. One must pay all of it, not 50 k€.

> *I would say one have to look through the original euro value, and one must be prepared for the total price, not half of it. Because, if the risk realises, it will realise as whole or not at all. – – Personal injury or image risk are good examples of what can be considered to have a low likelihood but the shocking price. There is a place for analysis when the risk level of injury shows ten k€ because the percentage is small. It does not look so bad, but again someone may die, so maybe the risk level is not right. (Interview 16.)*

> *If you think the entire total sum of risk levels, maybe the average is correct. Some of the risks realise and some not. (Interview 6.)*

In conclusion, the quantitative analysis method was concerned as a suitable and transparent way for economic risks that have direct cost effects on the projects. However, risks that do not have direct cost effects in project-level are challenging to analyse in numerical terms.

3.3.5 Risk evaluation

In the interviews, the question related to risk evaluation was "How are risks evaluated, or in other words, how the choice about do risks need treatments is done?" Most of the interviewees, with whom risk evaluation was discussed (7/9), told that all the risks listed to the R&M-analysis tool, need treatments. They do not record risks that have small consequences or likelihood. Also, risks which likelihood is significant, and consequences are minor are not recorded to the tool.

> *We only record risks that have been found to need some measures. So there [R&M-analysis tool] is not such [risks that do not need treatment] risk. Because if we do nothing, then we think it may not be a risk. (Interview 7.)*

Interviewees who did not plan treatment to every risk told that they focus on risks that are most significant and likely to realise (Interviews 4 &16).

> *We can quite well say what is important and what is not by experience. For example, pacing works (tahdistava työ) – – are highlighted (Interview 4).*

Interviews brought up that risk prioritisation, meaning the order in which risks are treated, is done based on the level of risk. According to the questionnaire, the average grade for the difficulty of prioritisation of risks was 2.55 in 1 (very easy) to 5 (very difficult) scale. One interviewee mentioned that one should always think what the cost of treatment is, so if the treatment is more expensive than the consequences of realised risk, then, of course, there is no sense to implement the treatment. However, there is no instructions or criteria on how to evaluate risks. (Interview 2.)

3.3.6 Risk treatment

Interview questions related to risk treatments were “Have you planned risk treatments?”, “If you have, what kind?”, “Are the planned treatment measures actually implemented?”, “Have the planned and implemented treatments worked as intended”, and “How are the treatment measures monitored?”

Common threat treatment strategy that is in use is threat reduction by reducing the consequences or likelihood of risk realisation. In the tender phase, threat transfer is also commonly in use. (Interview 2.) According to the interviews, in the tender phase, threat treatment is often included in the tender price. For example, if there is a structure where is the threat of falling, the cost of fall protection is added to the tender price.

When the level of implementation of planned risk treatments was discussed, answers differed between two options. About half of the interviewees (6/10) told that when they plan treatment, they always implement it.

> *If I [construction manager] and the site manager both think that [the treatment] should be done, then yes, it will be done (Interview 1).*
>
> *[Risk treatments] have been implemented. We do not promise things that we cannot stick. (Interview 10.)*

Furthermore, the other half of the interviewees (4/10) revealed that planned treatments are not always implemented. It was also pointed out that the post-analysis of realised risks is often not carried out.

> *Not all [planned riss treatments] will come true. – – There have been several times when risk is identified, and even treatment measures planned. However, threat has been realised. Furthermore, there has not been an analysis of why it realised. The threat and its realisation are swept under the rug. (Interview 11.)*
>
> *We identify threats and think about risk treatments, but we are not able to do the post-analysis. We can state if threat realised or not. However, we are not able to say does it realise because we did not take treatment measures, or did it realise despite the treatment. We do not analyse far enough those things. (Interview 2.)*
>
> *An interesting phenomenon is that once there has been that poor project, and one should keep its post-analysis, and just when there could be learning available, the post-analysis is not done. Good sites are post-analysed. – – But there is not much to learn. – – The kind of projects where would be something to talk about, nobody has been there to tell what went wrong. (Interview 10.)*

The questionnaire asked respondents to rate the difficulty of the planning and implementation of risk treatment. Answers are presented in Figure 35. The implementation of planned treatment was considered to be more complicated than planning. According to the interviewees, the effectiveness of the risk treatments is not systematically monitored. However, one interviewee mentioned that the effectiveness of the treatment measure is checked when the risk status is updated (Interview 6).

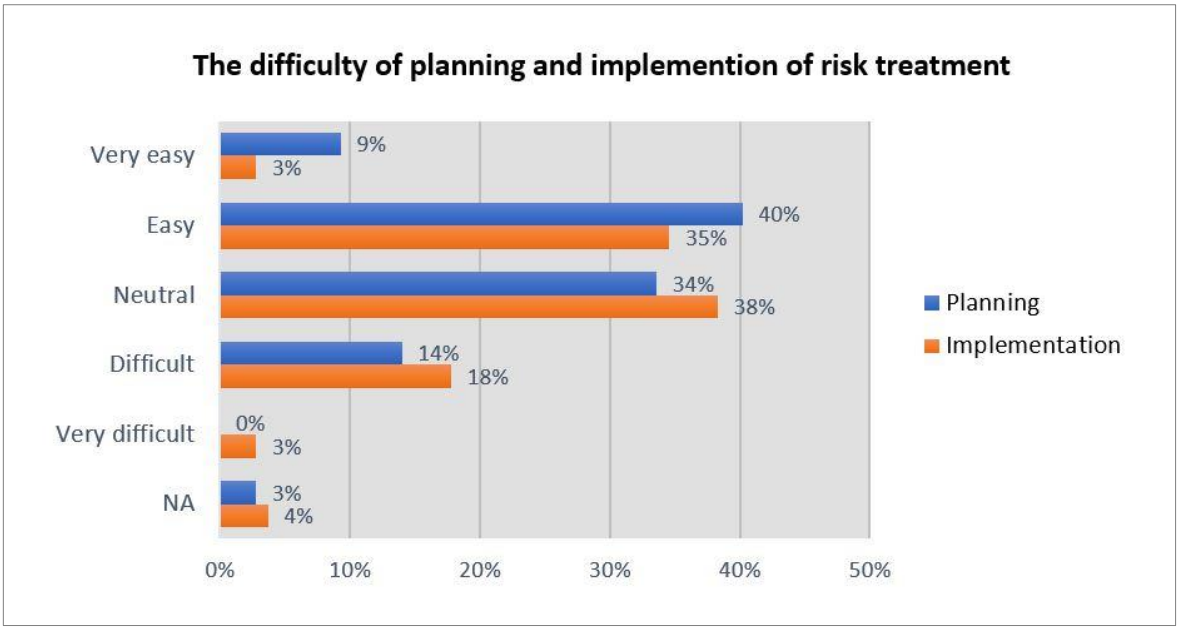

Figure 35. The difficulty of planning and implementation of risk treatment (by the questionnaire, n=107).

3.3.7 R&M-analysis tool

The R&M-analysis tool was already researched in the documental study but from the instructions point of view. This section aims to describe the tool from the perspective of the users of the tool.

Among interviewees with whom the R&M-analysis tool was dealt with 3/18 considered tool as a good, 5/18 as a neutral, in which three mentioned that they could not come up with a better solution, and 9/18 thought that the tool needs improvements. The results from the questionnaire are in line with the interviews. To begin with, 61 % of the questionnaire respondents have been using the tool by themselves, and the rest 39 % have not. Among respondents who told they have been using the tool, were asked to evaluate different aspects of the tool. The average grades in 1 (very poor) to 5 (very good) scale for the aspects of the tool was as follows:

- tool accessibility from the Pro3-system: 3.55
- tool usability: 2.85
- tool clarify: 3.02
- speed of the use of the tool: 2.86

The overall rating of the tool is as presented in Figure 36. The average grade was 2.89, which means that the tool is concerned to be more poor than good. Noteworthy is that the tool was considered as ‘poor’ by 31 % of the respondents. However, interviews and questionnaire revealed that the most significant improvement area related to the tool is that the risk analysis is quantitative. Therefore, it may have lowered the rating of the tool. However, this development point does not directly consider the tool itself, but the process customisation.

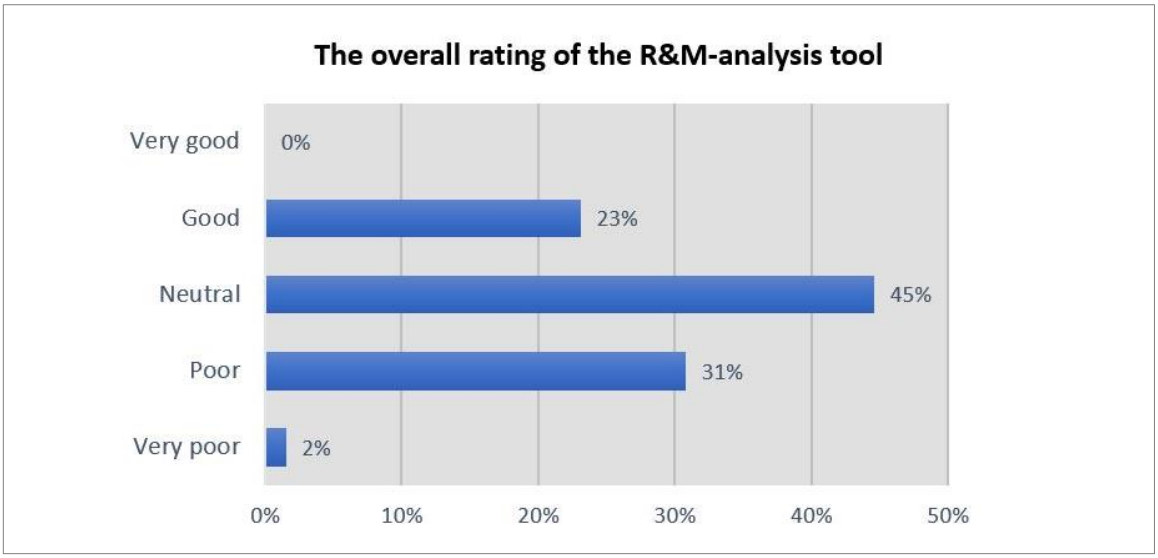

Figure 36. The overall rating of the R&M-analysis tool (by the questionnaire, n=65).

According to the interviews, the most crucial defences were in the usability of the tool. The tool was negatively described with words 'cumbersome', 'clumsy', 'onerous', and 'slow to use'. Features to be developed are not described here, but they are introduced later when the improvement proposals for the case company are given in subchapter 5.2.

As positive aspects of the tool, the questionnaire respondents considered, for example, that with the tool, risks are listed in one place. Furthermore, the tool certainly makes one think more about risks when one has to determine numerical values for the consequences and likelihood. The tool is also transparent for everyone to see and use it.

Most of the interviewees (7/8) told that they use the R&M-analysis tool already in the tender phase. An interviewee who revealed that the primary tool in the tender phase is a different notebook explained that the current tool to be used does not meet their need. They need a tool where notations are easy and fast to write down. However, risks are recorded to the R&M-analysis tool when the project is close to the tender presentation. (Interview 3.)

Approximately half of the interviewees brought out that during the construction phase, the tool is not updated, or it is negligently updated because they must do it (11/23). However, an overview is that risk management is done, but the importance of updating and recording new risks to the tool has not been understood.

> *[In construction phase:] We have not seen why this building would be better finished when we record things in it [R&M-analysis tool]. – – No one has been able to convince me why it is necessary. – – It is forced by the quality system because it leaves a trace when the last update is done. (Interview 1.)*
>
> *Nowadays, the tool must be updated every month. That does not tell anything about that content, but at least somebody goes there once a month. (Interview 2.)*

According to the questionnaire, 79 % of 65 respondents also record other risks than the project's economy-related risks, such as imago or nature risks. 12 % revealed that they do not. The rest 9 % could not answer.

3.3.8 Risk management competence

This section aims to give an overview of the risk management competence in the case company. The subject is considered through three aspects: acquirements, training, and instructions.

The questionnaire asked respondents to estimate their risk management skills. Among 107 respondents, 43 % considered their risk management skills to be 'neutral'. 38 % considered their skills to be 'good' and 6 % as 'very good'. Furthermore, 6 % of the respondents choose the option 'poor' and 1 % choose the option 'very poor' to describe their risk management skills. Interviews aimed to found out how interviewees have acquired their risk management competence. Almost all interviewees emphasised the importance of experience. They felt that the best experience comes from doing the work itself. Often, the experience is achieved through failures, in more detailed, when risks are realised.

> *You learn when you see reasons and consequences. The best lessons you can learn happens in practical work-life at the site. (Interview 4.)*

A couple of interviewees (2/25) told that they have learned risk management skills from school, for example, from project management courses (Interviews 14 & 16). In addition to work experience, interviews brought out that also conversations with colleagues and managers have improved their risk management competence. One respondent told that reading articles about construction industry may have been helpful (Interview 5).

Interviewees brought out that the case company has its in-house production management training, called 'Tuotannonjohdonkoulutus' or TJK. It consists of nine sections, which each takes one working day. One of the sections focuses on project risk management. The training is mandatory for employees who are working in the construction phase (Interview 2). However, out of 107 questionnaire respondents, 22 % has not taken any sections, and 24 % has taken only a few sections. Figure 37 represents the distribution of answers.

Figure 37. The distribution of taken TJK-training sections (by the questionnaire, n=107).

When questionnaire respondents (n=107) were asked about the usefulness of risk management training, 35 % concerned it as useful, 2 % as impractical, and 63 % could not say. The questionnaire also had the following question: “If NCC would offer risk management training (separate from TJK), would you attend?” Out of 107 respondents, 58 % answered they would attend, 7 % admitted that they would not, and 35 % could not say.

All the interviewees with whom the in-house training was talked about, though it valuable. Company's internal training was seen useful because it unifies practices inside the company's operation.

> *It [in-house training] could be useful because this company is a company where every department should work by following the same process. I have a feeling that right now, in our unit, we work just as one feels to be the best. There is not a standard mode of operation. (Interview 1.)*
>
> *I feel that in-house training is quite good, because of two reasons; it is company-specific, so it deals specifically with what the company wants. Another good thing about it is networking. (Interview 15.)*
>
> *Yes, all training, for example in quality or cost control, project management, or YSE-training [General conditions for building contracts] in its way, improves the capacity to manage risks. (Interview 23.)*

However, there was a couple of interviewees who had their restrictions about in-house training. One did not think there is a need for a separate training for risk management because the level of risk management is quite good already (Interview 6). Another interviewee was afraid that nobody would attend. (Interview 15). The third thought that the training is not the most important, but the continual discussion is the crucial factor in the improvement of risk management (Interview 20). Two of the interviewees (2/22) told that they have been in risk management training organised by an outside body (Interviews 2 & 10).

One source for information about risk management is the company’s instructions in the operating system. However, the questionnaire revealed that out of 107 respondents, 48 % have not read it. Furthermore, 32 % answered that they had read it, but more than three years ago. The rest 20 % have read the instructions during the past three years.

The questionnaire had the following question: “Could you tell where the instructions can be found?” Only 7 % out of 107 questionnaire respondents answered they know precisely where to find them. 32 % chose the option “I know approximately, but it might take a few clicks to find them”. 36 % answered that they know, but only at the level that they are in the Pro3-system. Noteworthy was that 25 % answered they do not know where to find the instructions.

The results of the interview were similar. Most of the interviewees (8/14) told that they know there are instructions for risk management, but they do not know where to find them. One of the interviewees told that he or she tried to find them but could not (Interview 7). Rest (6/14) have read instructions. Among these six interviewees, one interviewee described instructions to be good. Three interviewees would like them to be better. As an improvement, instructions were hoped to be more comprehensive and to provide more guidance on quantitative risk analysis. One interviewee told that he or she could not find an answer to the problem from the instructions and had to turn to a colleague. Furthermore, one interviewee

mentioned that the information should not be distributed on the internal website and operating system, but the information should be concentrated in one place.

> *Clear guidelines would be needed to assess the value of risk. I think there is too much variation in the pricing of risks. (Questionnaire, open response option.)*

Interviewees were also asked to describe how they know how risk management should be done when they do not know where to find instructions. They told that colleagues and managers have a significant role. Especially the significance of construction manager was emphasised.

> *The guidance on how to do risk management comes from the construction manager (Interview 7).*
>
> *In my opinion, there has never been any training or instruction about the use of the tool. It [the tool] just appeared to the Pro3-system one day, and to we were told this is what we use. (Interview 9.)*

3.3.9 Flow of information

Information flows in many directions inside an organisation and its projects. This subchapter considers the flow of risk management related information from the project point of view. It aims to collect data about the case company to communication & consultation and recording & reporting components of the process by ISO 31000:2018.

The first direction is the flow of information **throughout the project lifecycle**. It means the movement of information 1) from the tender phase to the construction phase and 2) from the construction phase to the warranty phase. At these points, the data transfer is essential because the personnel of the project may change a lot. According to the interviews, risk management information flows through the project lifecycle satisfactory.

When dealing with the flow of the information from the tender phase to the construction phase, it turned out that the significant development has already happened thus the R&M-analysis tool can already be opened at the tender phase.

> *I see as an essential development point that has happened that it [R&M-analysis tool] can be opened already at the tender phase. For a long time, we were living in a phase where those risks identified in the tender phase were recorded to some Excel-sheet from which the information never passed anywhere, and it was not in any system. (Interview 3.)*

However, even though the tool can be opened already in the tender phase, information is not always systematically recorded to the tool. In addition to the R&M-analysis tool, information is transferred via 'project transfer from tender phase to construction' meeting (projektin siirto tarjoustoiminnalta tuotannolle -palaveri), where risks identified in the tender phase are presented to the site personnel. According to the interviews, although the policy is outlined in the guidelines of risk management, it is not always followed. Construction managers are usually involved in the project in both phases. Thus, their importance in the flow of information is significant.

From the construction phase to warranty phase, the primary tool for information transfer is 'after-sales review' (jälkimarkkinoinnin katselmus).

> *We have after-sales review, that is arranged one or two months before the building is ready. In that meeting, we [after-sales managers and site] go around the building and look at what kind of threats there are from the perspective of after-sales. We ask [from the site personnel] if there is something that we have noticed to be a problem repeatedly. (Interviews 12 & 23.)*

Also, after-sales can use the information that is recorded, such as quality review, site meeting minutes, photos, and plans as their help. The R&M-tool is not used in the warranty phase.

Next concerned flow direction for risk-related information is **from after-sales to construction or even to tender organisation**. Only two interviewees were from after-sales, and they were from the same department (Residential Construction Helsinki). Therefore, this information cannot be extended to the entire company. However, these two interviewees from after-sales described the exchange of information as follows:

> *When we find deviation in quality or product, we try to inform it to production, design control, and procurement (Interview 13).*
>
> *It may not have even been realised that something is a threat, but sometimes it comes down to the fact that we realise it in many different places, so we try to inform production so that they can prevent that risk (Interview 12).*

One practice mentioned for information transfer is when expanded management (laajennettu johtoryhmä) have meeting. There after-sales has a section, where they present observations from after-sales reviews. Then construction managers transfer the information to their projects. Also, after-sales prepares summaries about the problems or good practices that have been identified over the year. (Interview 13). However, interviews brought out that there are differences between departments.

> *It is close to zero what information comes [to production] from [warranty phase] at least in our department (Interview 10).*

Information should also move horizontally **between projects inside one department**. According to interviews, the case company has no tool or procedure to spread information comprehensively. The flow of information between projects is based on the exchange of information between individuals. Information may also transfer in various management meetings, but it is not systematic. Interviewees highlighted the importance of the construction manager.

> *[Information] transfers partly, because construction managers have many projects, so the information flows between these projects. – – There should be more sharing of information. Of course, when site personnel changes from one construction manager to other, and then some amount of tacit knowledge always passes, but I do not think it is comprehensive. (Interview 4.)*
>
> *We have department meetings (yksikköpalaveri), and there these [risks] are inconsistently spoken, but it is not systematic (interview 10).*

According to interviews, the exchange of information **between departments** of the case company is minimal or not at all. Only safety risks are systematically communicated in the form of safety handouts or posters (Interview 6).

> *It is quite low between departments. Of course, projects that have gone badly wrong and if there is a prime project, the whole of Finland will hear about them. The average is wholly ignored. (Interview 15.)*

> *Between departments, to the extent that you know people from other units, yes, we call for a consultation at a reasonably low threshold. – – But it is a person-to-person interaction, and it is not something derived from the company. (Interview 16.)*

All data recorded to the R&M-analysis tool is stored to the common data bank. However, according to interviews, the data is not analysed or utilised in any way yet. Anyone can go to the data bank and see what kind of risks the projects have faced and what the costs have been. However, if one is not aware of the existence of the data bank but does not explicitly look for information about realised risks, it is unlikely that they will come across the information. (Interview 2.) Nonetheless, there was a desire for someone to go through the data and find out the most often realised risks and inform projects about them (Interview 10).

Among interviewees, possible increase in information exchange was considered useful. However, it was seen as a complicated challenge because the culture in the construction industry is the kind where failures are not sheared easily (Interview 11). In conclusion, data exchange between projects and departments is derived from individuals. There is no systematic course of action to the exchange of risk management information.

3.3.10 Resources

Interviews had a question about resources for risk management. This section was concerned in order to collect data about the framework where risk management is accomplished. The common opinion among the interviewees was that there are enough resources to do risk management. Resources discussed were time, personnel, and risk management competence. The only resource where flaws were seen was the tool. In the interviews, the time resource was described as follows:

> *There is definitely not too much time. But I could see that we focus on risk management in our projects. – – You must always find resources and time to do it. However, sometimes we have everything else in a hurry, so we must do the risk analysis a bit faster or then postpone the meeting for two weeks. (Interview 17).*

> *I think that the time to take care of things can be found when one knows the importance of it (Interview 18).*

3.3.11 Monitoring and review

According to the standard ISO 31000, monitoring and review -component should be applied in addition to monitoring and review of risk management actions also to monitor and review the process itself. Furthermore, the third aspect that should be monitored is the framework of risk management. Interview question related to a subject was: “How is your employer's project risk management monitored and reviewed?”

Interviews find out that the risk management operations in projects are reviewed in internal and external audits (sisäinen ja ulkoinen auditointi). A production jury (tuotantoraati) also visits in large-scale projects. All of these have a section about risk management, but it includes only reviewing a couple of risks and their management. Furthermore, internal audits review the usage of the R&M-analysis tool.

According to interviews, the risk management process is not systematically or officially monitored and reviewed. There is only a very informal discussion of the process and its effectiveness. One interviewee described the subject as follows:

> *Not systematically, probably. – – But the process is evaluated in audits. – – And then those changes are made or not. But of course, the team is continually thinking about it. It is our job to develop it [the process] and to move things forward so that we can do better in these matters. (Interview 20.)*

Neither the framework is reviewed. For example, one interviewee brought out that there have not been surveys about the R&M-analysis tool and how it should be improved.

> *The usage [of R&M-analysis tool] is assessed in audits. But an assessment of the usability of the tool has been forgotten. (Interview 7.)*

4 Synthesis and summary of results

This chapter aims to give answers to the main research questions, and it is divided into three subchapters based on these three research question. Answers to the research subquestions were already given in the previous chapter. Questions are answered from the case company's point of view. In the next chapter, these results are generalised to concern, not only the case company but also other construction companies.

This thesis is scoped to focus on the risk management process itself, and thus, answers are considered mostly from the process point of view. However, the risk management framework is briefly discussed due it affects the effectiveness of risk management. Also, the principles of effective risk management by ISO are shortly considered.

4.1 Alignment between the company's process and the process defined by the standard

The first research question is dealing with the relation between level one and level two. It goes as follows: "RQ 1: How well is the project risk management process defined by a construction company in line with the risk management process by ISO 31000:2018?" The comparison is made based on the literature review and documentary study.

From the components of the risk management process by ISO risk assessment and risk treatment can be defined in the project risk management process of the case company. It is easiest to detect by looking at the header row of the case company's R&M-analysis tool. In the process of the case company, *title*, *project phase*, *category*, and *description of the risk* correspond to the identification component of the process by ISO. The *value* and *likelihood* are proportional to the risk analysis -component of the process by ISO. The *level of risk* is a calculation made by the system. With this level of risk, risks are prioritised so that key risks are handled first. It corresponds to risk evaluation in the process by ISO. Finally, *treatments*, *due date*, and *responsible person* correspond to the risk treatment -component of the risk management process by ISO. Figure 38 illustrates the similarity of these processes.

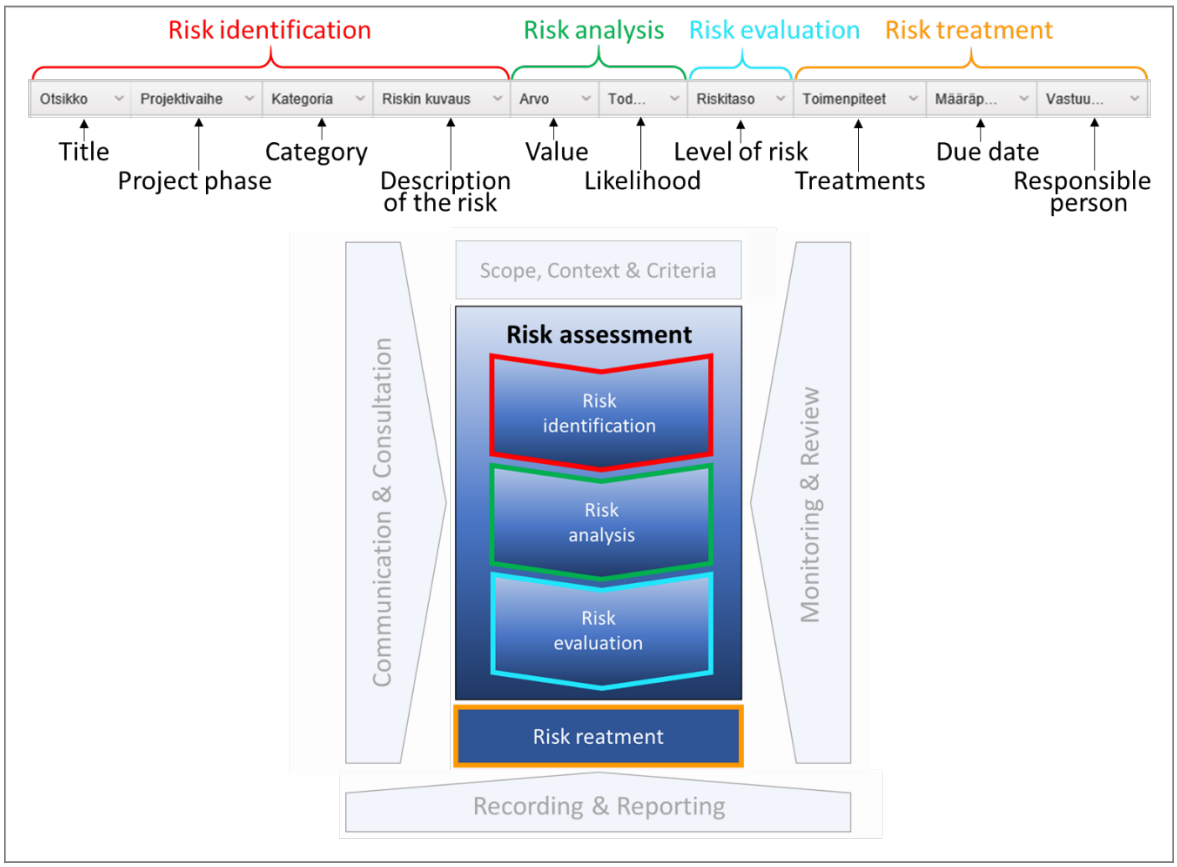

Figure 38. The similarity of process' components defined by the case company and the standard ISO 31000:2018.

Then, more specifically about the content of components discussed. According to ISO 31000:2019, risk identification aims to find, recognise, and describe risks that a project is facing. In the process of the case company, risks are first identified (title) and described (project phase, category, and description of the risk). ISO 31000:2018 defines that risk analysis focuses on the consequences and likelihood of the identified risk. Also, the case company determines that risks are analysed by consequences and likelihood. Both ISO 31000:2018 and the case company urge that in addition to negative risks (threats) also positive risks (opportunities) should be identified.

According to the process by ISO, risk evaluation means deciding if the risk needs treatment by comparing the results of the risk analysis with the defined risk criteria and prioritising risks. Risk evaluation in the case company means that the tool calculates the level of risk, and then, risks are prioritised so that the most significant ones are dealt with first. According to the interviews, most of the employees do not record risks that do not need treatment to the R&M-analysis tool. At this point, it is probably worth reminding that threat retention and opportunity ignoring are also risk treatment strategies. However, some degree of risk evaluation is done when it is decided if the risk is recorded to the tool or not.

ISO defines steps to be taken in risk treatment component. These are to formulate and select treatment options, implement the selected treatment, assess the effectiveness of treatment, decide if the remaining risk is acceptable, and if it is not, take further actions. Instructions of the case company are following ISO's guidelines. They urge to plan measures for risk treatment, implement the treatments, and monitor their success. After that, the risk

assessment should be revised to ensure that an acceptable level of risk is achieved. The status of risk should be determined and updated as the project progresses. ISO defines different threat treatment strategies that could be combined into four following strategies: threat avoidance, threat reduction, threat transfer/sharing, and threat retention. Case company's instructions introduce precisely the same strategies. Strategies are supported with examples, that will help the employee understand the main features of different strategies. Examples are only covering the treatment of threats, not the treatment of opportunities.

The risk management guidelines of the construction company are mainly focused on the risk assessment and treatment components of the ISO's process. Thus, the determination if the rest parts of the process by ISO exists and to what extent in the company's process is impossible to do comprehensively. However, a couple of observations are described next.

ISO determines that the risk management process and outcomes achieved through it should be recorded and reported with the appropriate method. The R&M-analysis of the case company is a tool for structuring the risk assessment process and a tool for risk recording. According to ISO, one aim of the recording and reporting component is to support decision-making. It is implemented due instructions of risk management encourage that R&M-analysis should be used to assist the economic forecasting of the project.

Scope, context, and criteria -component of the ISO 31000:2018 process includes establishing these aspects in order to customise the risk management process. From the guidelines of the case company can be seen that the list of possible risks to be identified and treatment strategies are scoped to serve the company. However, there is no defined common course of action, such as who, where and how often risks are assessed. This subject is considered more in the next subchapter. Furthermore, instructions do not provide risk criteria which could assist in evaluating the significance of risk or to deciding the amount and type of risk that can be accepted. The instructions urge to use the help of experts and calculations to analyse risks. There is no guidelines or instructions on how the likelihood should be defined and measured or how the consequences should be analysed. Also, there are no criteria to choose if the risk can be retained or do it need treatment. In the construction project point of view, risk criteria could be for example if the value of the risk is more than 100 k€ or risk involves the possibility of personal injury, risk has to be treated so that likelihood is 0 %.

Communication and consultation -component of the ISO's process seeks to increase the knowledge about risks of the project's stakeholders to obtain information to support decision-making. In the case company's instructions urge to make use of experts from different disciplines to assess the value and likelihood. Also, instructions of the case company give guidelines on how the information of risk should be transferred from the tender phase to the construction phase.

The monitoring and reviewing of the process are not described in the guidelines or instructions of the case company. Only monitoring considered is risk monitoring, but it is part of the risk treatment component. In conclusion, the risk management process defined by a construction company is in line with the ISO 31000:2018 process what comes to the risk assessment and treatment components. The guidelines focus on the actions towards individual risks, not the process itself.

4.2 Alignment between the company's process and its implementation

Research question two concerns the relation between levels one and two and goes as follows: "RQ2: How well do risk management operations in projects follow the project risk management process defined by a construction company?" Based on empirical study, risk management operations in projects are mostly done according to the company's guidelines. However, as mentioned in the previous subchapter, the guidelines are relatively concise and cover mostly risk assessment and treatment components. Next, these components are dealt with by comparing the guidelines and implementation of them.

Risk identification is instructed to be made by considering various aspects of the project, such as the client, contract, the difficulty of implementation, occupational safety, and the competence of the project organisation. In reality, risks are identified from the sources described in the instructions. Instructions urge to make the risk identification together with different areas of expertise or experts. Interviewees highlighted the value of teamwork risk identification. In reality, risks are identified in many projects by various parties, such as legal department, site managers and procurement engineers. However, interviews brought out that there might be a case that risk identification is entirely down to the responsibility of one person. However, the overview is that the identification is made mostly by multiple authors.

Instructions urge both negative risks and positive risks to be identified. However, according to the interviews, the opportunity identification seems to be overshadowed by the identification of threats. The most likely reason, according to the empirical study, is that opportunity identification is concerned to be more challenging than threat identification.

Based on the empirical study, risk analysis is done according to the guidelines in projects; risks are analysed quantitatively. It means that the consequences of realised risk are estimated in euros and likelihood of risk realisation is estimated in percentages. However, the guidelines do not assist the quantitative analysis. Results vary a lot depending on the employee or team who is doing the analysis. Furthermore, risk analysis was concerned to be challenging. Risk evaluation is as well done as instructed; risks are prioritised so that key risks are handled first.

Risk treatment gets most of the attention in the instructions. Instructions separate risk identification into stages, which are the planning of treatments, implementation of treatments, and updating the R&M-analysis tool. In the last stage, the effectiveness of the treatment is reviewed. According to interviews, this component of the risk process is implemented most poorly. Treatment options are planned, but the implementation is often halfway there. One reason may be the result of the questionnaire that implementation of treatment is considered more challenging than planning of it. Also, the review of the treatments' effectiveness is often forgotten. Instructions urge that risk should be followed until it is passed in the project timeline. However, according to the interview, the monitoring of the risks after the treatment is implemented poorly. Furthermore, the analysis of residual risks and post-analysis of realised risks are often disregarded entirely.

Then, risk management practises are concerned. According to interviews and the questionnaire, there is much variability in practices among projects. Practises vary depending on the project organisation, and more specifically on the construction manager or

site manager. However, practices in the case company can be roughly summarised into the hierarchical division presented in Figure 39.

The first division is done based on if the risk management is done together in a brainstorming kind of meeting or workshop, or if it is done separately by individuals. If risk management is done together, it can be assumed to be more effective because if the assessment is done according to one person and his or her risk management competence, some risks may remain unidentified. Furthermore, if the person responsible for risk treatment does not participate in the planning of treatment, there is a threat that the treatment will not be implemented. When risk management is done together, there is always more experience and expertise available. Also, according to the literature review, brainstorming can encourage and stimulate a group of people to develop ideas. Thus, by doing risk management together, risk identification is more effective.

As presented in the hierarchical division in Figure 39, some of the projects have a separate risk management meeting, and some include risk management into other meetings, such as the construction manager's follow-up meeting or weekly meeting of the site. Rectangles on the bottom line of Figure 39 concern the recording of risk management operations. Finally, one can construct five different models for risk management practises used in projects. Models are marked with colours based on the literature research and empirical study, so that green colour represents more effective, and red represents less effective practice for risk management. Therefore, it means that project organisation should strive towards model number one (green colour).

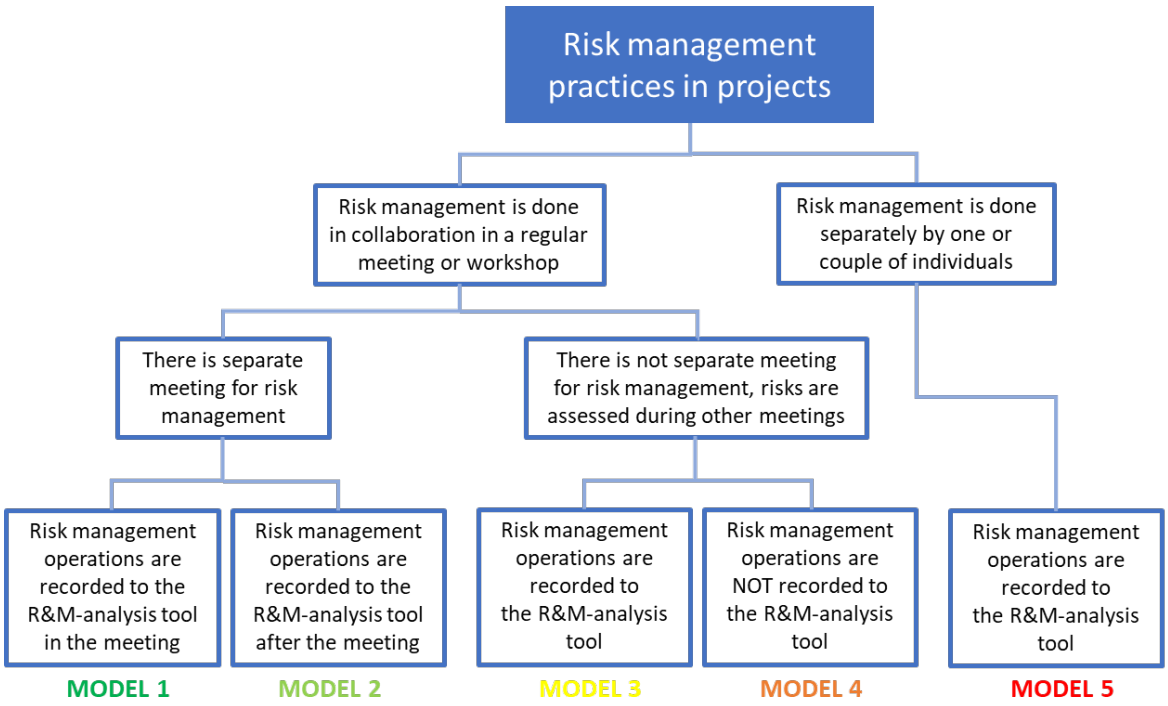

Figure 39. A rough hierarchical division of risk management practises in projects. Note that figure is a generalisation. Thus, there can be other practices in use.

Risk management operations in projects can be divided into two operations. The one is actual risk management operation, and the other is a recording of the risk management operations and updating the recording tool. Among projects, there is variability in the combination of

these operations. Some projects do them separately, and some combine them. With the latter one, a project's risk management is usually built around the tool. According to the empirical study, a rough statement is that, if risk management recording is a separate action from the risk management, the recording is typically 'a must-do', and the value of recording the operations is often not understood.

According to principles of effective risk management by ISO 31000:2018, a structured and comprehensive operating model for risk management contributes to consistent and comparable results. Also, the risk management framework highlights that the top management of the organisation should demonstrate leadership and commitment by planning a course of action. However, based on empirical study, the case company's course of risk management action remains unclear, and that may be the reason for the variation of practises in projects.

4.3 Alignment between risk management operations in the projects and the risk management standard

The last main research question is: "RQ 3: How the risk management activities in the projects correspond to the activities ISO 31000:2018 has defined?" Part of the observations about the relationship between risk management operations and ISO 31000:2018 were already covered in previous research questions. For example, identification of opportunities between levels 1 and 2 is in line, but between levels 2 and 3 it is not. Thus, the identification of opportunities in level 3 cannot be in line with level 1. The same applies to risk treatment. Otherwise, risk identification, analysis, evaluation, and risk treatment are made as ISO 31000:2018 recommends.

When comparing what ISO defines and what is done in projects, one significant deficiency comes from project customisation in the risk analysis component. According to ISO, process customisation aims to make it suitable and effective for the project in question. The customisation is done in scope, context, and criteria -component of the process by defining the scope and more specifically, considering the appropriate method for risk analysis. Also, one principle of effective risk management by ISO is that the risk management framework and the process should be customised and proportionate to the organisation's external and internal context related to its objectives.

Now, the case company analyses its risks with a quantitative method. Risks are given numerical values in terms of consequences if the risk realises and the likelihood of the realisation. According to interviews and the questionnaire, the quantitative analysis of risks, that do not have a direct economic impact on a project was considered a difficult task. Furthermore, quantitative analysis of these risks creates conflicts between risk analysis and cost management of the project. The total sum of risk level should be approximately the same in the project's risk letter in the cost management system and R&M-analysis tool. Nevertheless, if there is a risk that does not have direct cost effects in the project level, the sum in the cost estimation of a project and R&M-analysis cannot be the same. Thus, the quantitative analysis of the risks that do not have a straight economic impact on a project is an ineffective method.

Communication and consultation should take place throughout all steps of the risk management process. Communication and consultation -component aims to bring different areas of expertise together, in order to ensure, for example, that different views are appropriately considered when defining risk criteria and evaluating risks. Interviews aimed to sort out how communication and consultation are done in the projects of the case company by sorting out how the risk related information flows in the company. This risk-related information can be, for example, when someone asks for a consultation, when the most commonly realised risks are communicated, or when the project's tender organisation informs its construction organisation about risks they have identified. Figure 40 presents the flow of risk management related information across the case company. Outside of the figure, communication and consultation happen also between individuals, for example, when a site engineer asks for help in risk analysis from the site manager.

In conclusion, communication and consultation through the project lifecycle are working well. Case company's risk management guidelines have instructions for information flow from one phase to another. Information's flow between projects inside one department is based on the information exchange between individuals. There is no systematic, comprehensive course of action for that. Information exchange between departments is at a very low level. And finally, the information exchange from after-sales, upwards to construction and tender organisation varies between departments.

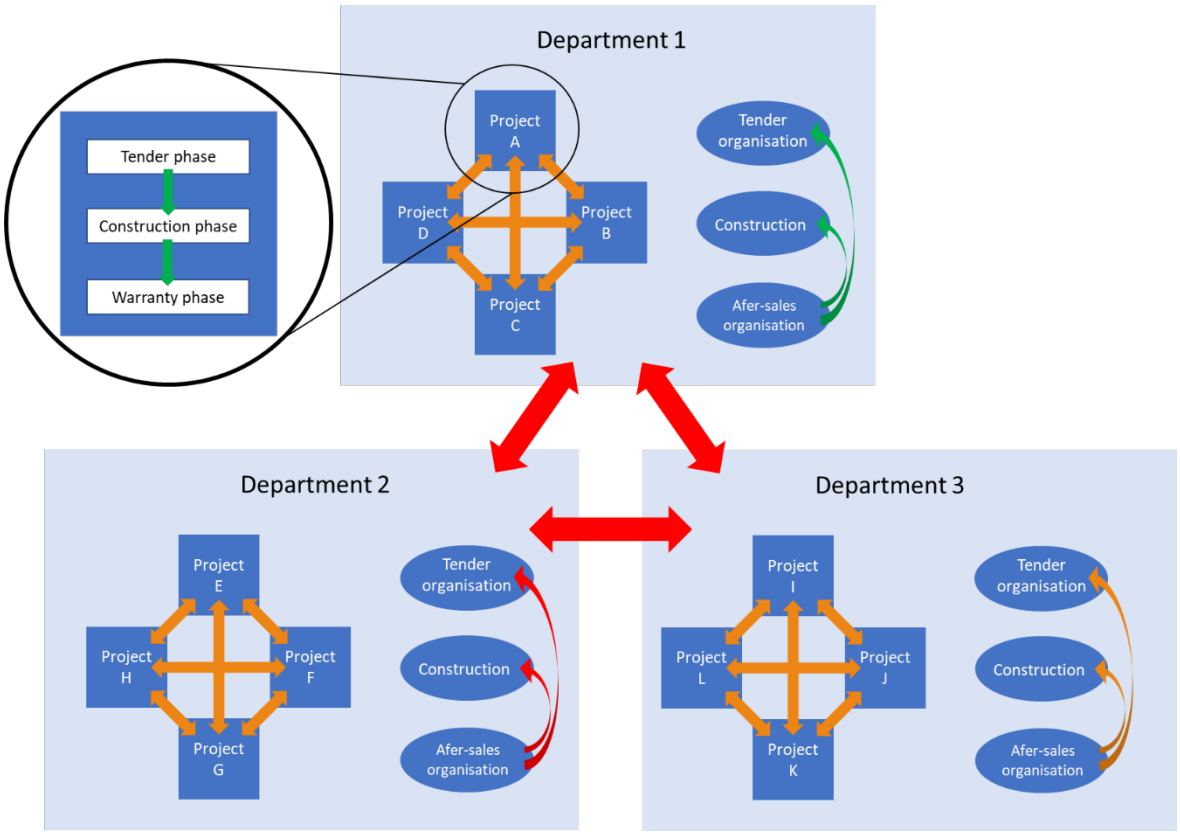

Figure 40. Illustration of the risk management information's flow across the case company. Arrows' colours indicate the level of information exchange; green colour indicates good, orange indicates moderate, and red indicates poor.

The risk management process and outcomes achieved through it should be recorded and reported with the appropriate method. The purpose of reporting and recording is to improve the communication about risk management activities and outcomes across the organisation. The case company has a tool for recording. As described earlier, there is no reporting that could help with communication across the organisation. Only safety threats have been reported systematically. The study also revealed that realised risks are not always post-analysed

ISO defines that risk management process and its framework should be regularly monitored and reviewed in order to make sure it is working as planned. The empirical research revealed that the process or its framework is not systematically monitored or reviewed in the case company. Only risk management operations in projects are reviewed, for example, in audits. Thus, the framework is not reviewed; the evaluation and improvement of the framework are deficient.

Resources are highlighted in various components of the risk management framework by ISO. For example, in leadership and commitment component of the framework, top management of the organisation should demonstrate leadership and commitment by ensuring that the necessary resources are allocated to managing risk. According to the empirical study, resources were otherwise considered sufficient, but the tool for risk management should be improved. Currently, it is considered not even mediocre. Other resources, such as time and competence, were considered good.

As a conclusion risk management in the case company's projects is done largely as the risk management standard defines. Risk assessment, which consists of risk identification, risk analysis, and risk evaluation, and risk treatment, follows the standard well and the main features of these components are in accordance with the ISO standard. The most significant differences come from the other components of the process.

At first, the risk management process and framework should be monitored and reviewed more systematically in order to meet the guidelines of ISO. Also, communication between departments should be added in order to increase risk management competence across the company. Recording of risk management activity is mostly done. However, it would be more effective for the projects if the recording would be included in the routines, and if its importance and benefits would be better understood.

According to the standard SFS-ISO 31000:2018, the effectiveness of the risk management process depends on its inclusion in the governance of project organisation and decision-making. According to the empirical study, risk management in the case company has developed tremendously in recent years. Currently, risk management is an integral part of daily operations in projects.

5 Discussion and conclusion

5.1 Applying the risk management standard to the risk management process of a construction project

The objective of this thesis was to study how the risk management standard can be applied to the risk management process of a construction project. The objective was studied through case company, and thus, this subchapter aims to conclude the results of the case study so that they are generalised to concern other similar construction companies and their projects as well. Criteria for the similar construction company is that it has multiple ongoing projects, it is divided into departments, and operates in developed countries. Although the generalisation of the results is typical for case studies (Aaltola & Valli, 2007), the limitations of the study from the generalisation point of view are considered in the subchapter 5.3

Business in the field of construction is risky. It is due to many features such as the unique end-product, complicated processes, and a large number of stakeholders. In the construction industry, effective risk management is the key to success. As highlighted in the literature review, there are various theories and strategies for risk management. This thesis used the process by the standard ISO 31000:2018 as its framework.

Based on the literature review and empirical study, the standard can be applied in construction project risk management. However, the risk management process by the standard ISO 31000:2018 may seem complicated and theoretical. Thus, it is essential to customise the process so that it is possible to implement effectively. The case study brought out also several factors that should be taken into consideration when applying the risk management process by ISO to the risk management process of a construction project.

Generally, risk management is a rather challenging task to motivate employees because the benefits of it cannot be seen right away. Thus, benefits achieved through risk management are easier to realise if risk management is at a poor level. However, the level of risk management is mostly an attitude-based thing, and it is essential to integrate it into the governance of the organisation and to all organisational activities. Furthermore, one way to increase motivation and understanding of risk management is through risk management training.

Risk management should be consistent between projects of the company since a consistent course of action contributes to consistent and comparable results. Also, project organisations vary a lot in construction. Thus, if a common course of action is not defined and implemented, risk management practices vary between projects. It leads to the situation that employees must learn a new way to work always when they change project. Therefore, much unnecessary work is done. In addition to planning and implementation of the common course of risk management action, it should also be monitored and reviewed, in order to ensure that they are implemented and work as planned.

The customisation of the process to serve the needs of the construction company and its projects is essential in order to make the process effective. According to the empirical study, aspects that should be focused on is, for example, defining the company's risk criteria, so that employees have precept on how to assist and deal with risks. The company should also choose the method for risk analysis so that it is compatible with the criteria and the purpose

of the process. It could be beneficial to concern and choose whether numerical data should be carried out or is qualitative analysis enough for the needs of decision-making.

Risk recording and reporting increase the improvement of the risk management operations by increasing the risk management competence, assisting decision-making, and increasing communication between stakeholders. The base for effective risk recording is suitable, fast, and easy to use the tool. Communication, consultation, and reporting are key factors so that company could learn from its own mistakes. For example, reporting the most commonly realised threats could prevent the company from making the same mistakes repeatedly. Furthermore, a critical condition for continuous learning is the post-analysis of realised risks, which seems to be easily forgotten.

Then, when an organisation is applying the process, it should consider doing they have enough appropriate resources. Resources include several factors, such as people and their competence, skills, and experience. Also, training programs, methods and tools used to risk management are concerned as resources. Furthermore, available time is an important resource for effective risk management. The organisation should note that at worst, the absence or inadequacy of a single resource can significantly reduce the level of risk management.

The last factor that appeared in the results is the identification of opportunities. Construction companies should focus more in addition to the identification of threats, also to the identification of opportunities. Especially before the tender is submitted, there may be big financial opportunities that should be recognised. However, the study revealed that the assessment of opportunities is overshadowed by the assessments of threats. This finding confirms the result of the research by Lehtiranta (2015) where 88 % of 66 construction project -related references considered a risk as a negative risk, and only 12 % considered a risk as a negative or a positive risk. The reason may be that according to the questionnaire, opportunity identification was a more challenging task than threat identification. Furthermore, the word ‘risk’ has a strong negative connotation. It means that when talking about risk management, people tend to associate it with detecting threats. Maybe risk management should be named as a threat and opportunity management.

Next, the contribution of this thesis to previous research is discussed briefly. As considered already in the introduction, there has been somewhat research about risk management in the construction industry. However, the research about the use of the standard ISO 31000:2018 in construction projects is relatively limited. Thao et al. (2014) researched risk management in construction projects based on the standard ISO 31000, but in Vietnam. However, in South-East Asia (excluding Singapore), construction project risk management is still in children’s shoes. Thus, research by Thao et al. is an introduction of the content and use of the standard. The contribution of this thesis to previous research on construction project risk management is significant due to its novelty. Similar, very broad and detailed descriptions of project risk management in construction company have not been made before.

5.2 Recommendations for the improvement of the project risk management

The purpose of this chapter is to give recommendations for the improvement of the risk management of construction projects. Although these proposals are made based on the study of the case company, they can be used in other similar construction companies. Criteria for a similar construction company are that it has multiple ongoing projects, it is divided into departments, and it operates in developed countries.

Customisation of the project risk management process

As the first development area, a construction company should increase the customisation of the project risk management process. It should be done in order to maximise the benefits achieved from work done and to minimise the unrelated work. As an example of the customisation that arose from the case study is that the case company should abandon the quantitative analysis of risks that do not have a direct economic impact on a project level. Based on the result of the empirical study, quantitative analysis is a suitable method for the analysis of economic risks. According to the study, threats that the employees consider as challenging to analyse quantitatively are related to the environment, brand of the company, occupational safety, and client. In these cases, it would be more fruitful to think about the cost of treatments instead of focusing on the cost of consequences.

In this example of process customisation, the company could analyse these 'non-economic' risks with scales, for example, as presented in Table 10.

Table 10. Scales for consequences and likelihood of risk.

Consequences		Likelihood	
1	< 10 k€	1	0 % – 33 %
2	10 k€ – 30 k€	2	33 % – 66 %
3	30 k€ – 100 k€	3	66 % – 100 %
4	100 k€ – 200 k€		
5	> 200k€		

The values selected from the scales would be set in a consequence/likelihood matrix. The colour of the spot in the consequence/likelihood matrix would correspond to the level of risk in question, as presented in Figure 41.

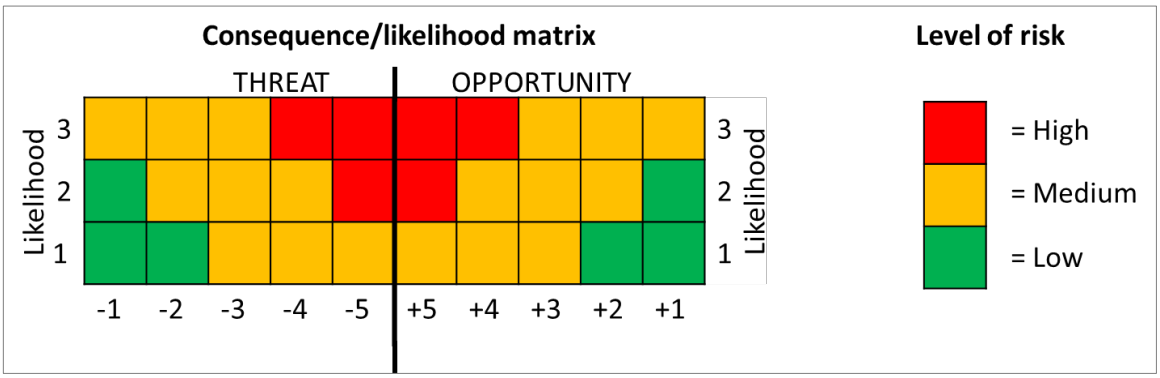

Figure 41. An example of a consequence/likelihood matrix and corresponding levels of risk.

As a result, the risk register could look as presented in Figure 42.

ID	Title	Project phase	Category	Description	Conseq.	Likelihood	Level of risk
1	Technical implementation of staircase	Construction	Technical implementation	Technical implementation of staircase is really difficult. There is a risk...	-3	2	Medium
2	Project organisation	Construction	Human resources	The project organisation has not worked together before.	-1	3	Low
3	Procurement of flooring	Preparation for construction	Procurements	Flooring can be purchased from new, cheaper manufacturer...	+2	2	Medium

The rest of the risk register's columns are not shown

Figure 42. An example of a risk management process' risk register with colour in the level of risk.

Companies that are part of a larger enterprise (like the case company) the omission of numerical analysis may be impossible. If this is the case, the focus of 'non-economic' risks should be transferred from risk analysis to risk identification and treatment. According to the empirical study, these are the most significant steps. A change of mindset should be driven by the upper management to operational managers and further to construction managers. Managers have a responsibility in implementing the mentality to site personnel.

Guidelines and in-house training in the harmonisation of risk management operations

The study revealed that practices for risk management vary a lot between projects in the construction companies. Some projects do risk management in collaboration using the expertise of the entire project organisation, whereas, in some projects, all risk management is delegated to a single person. However, according to the literature review, the practices should be consistent. Also, companies should have a common course of action, also in risk management.

According to the research, there are two critical issues in the harmonisation of practices; guidelines and in-house training. Guidelines should describe what the course of action should be. In the case company, it was found that guidelines were deficient. Questions that remained unclear were, for example, should there be a meeting for risk management, how often it should be held, who is responsible for projects risks management, and who should participate in the risk assessment. Even though some employees knew the answers, these practises should not be based on word-of-mouth. Everyone should be able to find these from the guidelines if needed. Furthermore, all information should be stored in one place. The study revealed that in the case company, the guidelines have been described in many places. Also, the guidelines should be easy to find.

Risk management training will harmonise risk management practices of a construction company. Furthermore, training will increase the risk management competence, and works as a motivator. Companies should ensure that the employees attend to the trainings. The empirical study revealed that even though the case company has its mandatory inhouse training (TJK), the rate of employees that have attended the training is relatively low. Especially, trainees and recently graduated employees could benefit from the in-house training. In companies, supervisors are responsible for ensuring that everyone has attended to the training. Another option is a register that keeps a record of those who have been trained.

In addition to the harmonisation of the risk management operations in projects, guidelines and in-house training should emphasise the importance of risk recording. Construction companies has many employees, also managers, who cannot realise the benefit of using the tool as the frame and recording tool of the risk management process.

Monitoring and review of the process

In construction companies, risk management operation in projects is usually monitored regularly. However, more emphasis should be put in the evaluation of the process and its framework. Evaluation would ensure that operations in projects actually works as planned and that the framework contributes to effective risk management.

Recording tool as a risk register

Based on empirical findings, the biggest reason behind negative attitudes towards risk recording and documentation is the tool to be used. If the recording tool that a company is using is slow and not intuitive, people tend to avoid using it. Companies should ensure that the tool is user friendly that means it easy and fast to use, and easy to find. The case study revealed that the case company should improve its tool with following suggestions:

- If there are many risks, they are distributed in multiple pages which makes the browsing slower. There could be a choice whether you want to see 10, 20, 30, or all the risks of the project on one page that could be scrollable.
- If a risk that is for example in the third page is updated, the tool returns to the first page, which makes browsing slow. Usually, one would like to continue from the risk that was just updated.
- There could be a tool so that one could see the update history. If a risk is updated, for example, treatment is changed, the user does not see what the original treatment was.
- Printing reports from the tool should be easier.
- The system does not send an e-mail to the defined responsible person of a risk even though the instructions say so.
- There should be an option to have the titles in English to make reportage easier.
- The tool is currently hard to find, so in order to get people using it, the tool should be made more accessible.

The aim of this subchapter was to make proposals for development of the risk management. This may have resulted in skewed impression that the current state of risk management in the construction companies is poor. However, the study revealed that in general, risk management in the case company is at a good level. In construction industry, much effort has already been put into risk management. Furthermore, the companies are on a steady track of continuous improvement, since employees have understood the importance and benefits of risk management.

5.3 Reliability and validity of the research

The empirical study was conducted with a case company approach. Due to the case study approach, all empirical data is compiled from one company. In this chapter, results were generalised to concern also other similar construction companies. The generalisation of the results is typical for case studies (Aaltola & Valli, 2007). However, there is a need to consider the reliability and validity of the research. Reliability is the ability of research to produce results that are consistent over time and replicable. Validity is the truthfulness and accuracy of the results and the degree to which the results measure what they are intended to measure. (Golafshani, 2003.)

The empirical research can be considered as reliable in the case company and in the conditions of the time when the study was conducted. However, the results may not be entirely reliable across the industry due to the case study approach.

The validity of the research was strived to maximise by the following considerations. The documentary study sought to present the data as comprehensive and original as possible. Interviews were conducted with wide sampling across the entire company. The interviewees had different backgrounds and job titles. Besides, the confidential nature of the interviews increased honesty and therefore, the validity of the results as well. The questionnaire had extensive sampling and a high response rate, which make results more valid. The validity of research could be affected by the fact that the researcher works in the case company, and she has her own opinions on risk management in the case company. However, own opinions of the researcher were deliberately kept as separate from the study as possible.

One source of critique is also the selected theory to be the base for risk management. Different theories were compared in the literature review. The selection of process by ISO is justified, among other things, by the fact that the standard ISO 31000:2018 has the status of a Finnish national standard. As described in the literature review, choosing a different process would probably not affect the results greatly.

However, the risk management standard has been criticised for the fact that it is "*not intended for the purposes of certification".* Also, for example, according to Leitch (2010) claims that the standard includes some idealistic requirements that are impossible to comply with if they are taken literally.

5.4 Suggestions for further research

The subject of this thesis is very broad to the frame of a master's thesis. Thus, there could not be an in-depth study of all the components of the process. This thesis focused on the implementation of risk identification, analysis and evaluation, and risk treatment in projects. Also, much attention was given to the risk management practises in the projects. As a suggestion for further research is more in-depth research of other components of the process, such as communication and consultation or the customisation of the process, which happens in scope, context, and criteria component of the process by ISO. Also, the framework of risk management and how it affects the effectiveness of the process could be studied.

This research was conducted as a case study of one construction company. The subject should be studied among a wider sampling of construction companies in order to get more reliable results. Also, it would be interesting to examine differences in courses of risk management action among different construction companies.

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List of appendixes

Appendix 1. The body of interviews

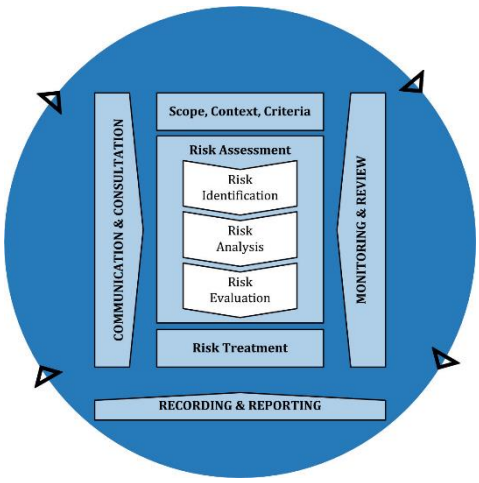
Project Risk Management – The Body of the Interview

This interview is part of empirical research for my master's thesis, which studies risk management in construction projects. The practical objective of the thesis is to improve the risk management process od the case company. The thesis and through it also the interview are limited to address specifically risk management of projects. All interviews are handled anonymously and thus, the answers that are used in my thesis cannot be associated with an individual.

1. **Background of the interviewee**
    a. What is your current job title?
    b. How long have you been working with your current job title?
    c. What kind of work have you done before your current job title?
    d. Which department do you belong to?
    e. How long have you been working for your current employer?
    f. Is project risk management part of your job description?
    g. Have you participated in the project risk analysis?

2. **Project risk management generally**
    a. What do you think project risk management means?
    b. How important do you consider risk management is in project management?
    c. What are the benefits achieved by risk management?

ISO 31000:2018 is risk management standard. It outlines the risk management process using the figure. Risk assessment is a three-step process that includes:



Risk identification

Risk identification involves the identification of risk sources, events, their causes and their potential consequences.

Risk analysis

Process to comprehend the nature of risk and to determine the level of risk.

Risk evaluation

Process of comparing the results of risk analysis with risk criteria to determine whether the risk and/or its magnitude is acceptable or tolerable.

(SFS-ISO 31000:2018)

3. **Project risk management in the case company**
    a. How is risk management of projects done in your department?
    b. Who do you think is responsible for project risk management?
    c. In what meetings are risk assessments conducted?
    d. How often is project risk assessment done?
        i. How often do you think it should be done?
    e. Who is participating in the project risk assessment meeting?
        i. Who do you think should be involved?

f. In which phases of the project risk management is done?
g. At what point do you consider risk management is most important?

4. Risk assessment and treatment

a. How are risks identified?
b. How are risks analysed?
c. How are risks evaluated, or in other words, how the choice about do risks need treatments is done?
d. Have you planned risk treatments? If you have, what kind?
e. Are the planned treatments actually implemented?
    i. Have the planned and implemented treatments worked as intended?
    ii. How are the treatment measures monitored?
f. How should risk management practices be developed?

5. Risk management tool (R&M-analysis)

a. What kind do you think is the tool? (Relevance, usability, clarity, functionality, etc.)
b. Are there any shortcomings or improvements in the tool?
c. How you feel the tool supports
    i. Risk identification?
    ii. Risk analysis?
    iii. Risk evaluation
    iv. Do you think value (€) multiplied by likelihood (%) is a good way to determine risk levels?

6. Risk management competence

a. Where have you acquired your knowledge of risk management?
b. Does your employer have instructions for project risk management?
    i. If so, where can you find it?
    ii. Do you think the instructions are proper? (Clarity, coverage, accessibility, etc.)
    iii. How does a new employee become familiar with the employer's risk management?
c. Does your employer provide risk management training?
    i. If it does, how often and have you found the training useful?
    ii. If not, should your employer provide risk management training?

7. Other

a. Is risk management information transferred from one project to another?
    i. If yes, how?
b. Do you feel that your employer has provided adequate resources for risk management? (Tools, time, human resources, etc.)
c. How is your employer's project risk management monitored and reviewed?

8. Free word – Do you still have something else related to the subject in your mind?

THANK YOU!

Appendix 2. The body of the questionnaire

Foreword:

Project Risk Management – Questionnaire for master's thesis

The purpose of this questionnaire is to map the level of risk management and risk management practices in the projects of NCC. All responses will be treated in strict confidence, and the results of the questionnaire will be completely anonymous. Therefore, I hope that you will answer the questionnaire with whole honesty. This is how I get the most out of the questionnaire. Thank you in advance!

- Anni Kankare

PART 1

1.1 What is your current job title?
1.2 How long have you been working with your current job title?
1.3 Are you a trainee?
1.4 How long have you been working in NCC?
1.5 In which phase of the project you work mainly?
Options: Tender / Construction / Both
1.6 How important do you consider risk management to be in project management?
Scale: 1 (unimportant) – 5 (very important)
1.7 What is the level of risk management in your ongoing or most recent project?"
Scale: 1 (very poor) – 5 (very good)

PART 2 (If answered *tender* or *both* to the question 1.5)

Risk management in the tender phase

2.1 In the tender phase of the project, do you have regular meetings, where the subject is risk management?
Options: Yes / No / I cannot say

PART 3 (If answered *yes* to the question 2.1)

3.1 Following table aims to find out who participate in risk management during the tender phase. Choose the best alternative for each job title. Job titles in the table*:* regional manager, operations manager, project manager, project coordinator, head of production, quality and environment manager, law department, safety manager, cost estimation manager, cost estimation engineer, purchasing manager, purchaser, HVAC-specialist, construction manager, and after-sales manager
Options: Always or almost always / Sometimes / Never / Do not attend but gives comments / I cannot say
3.2 Is there some job title missing in the table above? Below you can list the shortcomings and their inputs to risk management.
3.3 How often do you have risk management meeting in the tender phase?
Options: Once a week / Once a month / Irregularly a few times during the tender phase / Once during the tender phase / Something else, what?

PART 4 (If answered *no* or *I cannot say* to the question 2.1)

4.1 Describe briefly how risk management takes place during the project tender phase. Who is involved in the compilation of the R&M-analysis tool? Does someone it alone, or is it done together? Who is responsible for risk management during the tender process?

PART 5 (If answered *construction* or *both* to the question 1.5)

Risk management in the construction phase

5.1 Do you have regular meetings, where the subject is risk management?

Options: Yes / No / I cannot say

PART 6 (If answered *yes* to the question 5.1)

This section deals with project risk management, which should be recorded to the R&M-analysis tool in Pro3. The purpose is not to deal with day-to-day task planning, for example by foremen, although it is also an important part of the risk management.

6.1 Which of the options best describes regular risk management meetings you are having on-site?

Options: Can be seen from Figure 28.

6.2 How often do you have risk management meetings?

Options: About once a week / About once a month / Irregularly 4-6 times during the construction phase / Irregularly 4-6 times during the construction phase / Once before the start of the construction and once before the audition / Once during the entire construction phase / Something else, what?

6.3 Who is participating in the risk management meeting?

Options (multiple can be chosen): Construction manager / Site manager / Site engineer / Foremen / Site secretary / Something else, what?

6.4 How often do foremen participate in the risk management meeting?

Options: Always or almost always / Most of the time / Irregularly / Never

PART 7 (If answered *no* or *I cannot say* to the question 5.1)

This section deals with project risk management, which should be recorded to the R&M-analysis tool in Pro3. The purpose is not to deal with day-to-day task planning, for example by foremen, although it is also an important part of the risk management.

7.1 Which of the options best describes the risk assessment in your project?

Options: One person does the risk assessment based on his or her own knowledge / Risk assessment is done by one person, but he or she ask opinions from others / Risk assessment is done as teamwork / Something else, what?

7.2 Who is participating in the risk management meeting?

Options (multiple can be chosen): Construction manager / Site manager / Site engineer / Foremen / Site secretary / Something else, what?

PART 8

How easy or difficult do you consider the following components of the risk management process to be? Components can be seen in Figure 34.

Scale: 1 (very easy) – 5 (very difficult)

8.1 Have you used the R&M-analysis tool by yourself?

Options: Yes / No

PART 9 (If answered *yes* to the question 8.1)

9.1 How poor or good do you consider the following aspects of the R&M-analysis tool to be? Aspects: Tool accessibility from the Pro3-system, Tool usability, Tool clarify, Speed of the use of the tool, and the overall grade of the tool
Scale: Scale: 1 (very poor) – 5 (very good)

9.2 R&M analysis tool has a listing of common risks that projects are facing. Have you used the listing of pre-identified risks as a tool for risk identification?
Options: Yes, I use the listing all the time for the risk identification / Yes, I sometimes use it but not regularly / No, but I know there is a listing of pre-identified risks / No, I did not know about the listing of pre-identified risks

9.3 Do you record risks, that do not have a direct cost effect to a project to the tool? (For example, environment or brand risk)
Options: Yes / No / I cannot say

9.4 Free comment: What improvements would you recommend for the R&M-analysis tool?

9.5 Free comment: What is good with the R&M-analysis tool?

PART 10

Risk management training and competence

10.1 NCC has in-house production management training (TJK) that consist of 9 sections. Choose the best option.
Options: Can be seen from Figure 37.

10.2 One section deals with risk management. Do you consider risk management training as useful?
Options: Yes / No / I cannot say

10.3 If NCC would offer risk management training (separate from TJK), would you attend?
Options: Yes / No / I cannot say

10.4 What is the level of your risk management skills?
Scale: Scale: 1 (very poor) – 5 (very good)

PART 11

Risk management guidelines

NCC has instructions for risk management in the activity system.

11.1 Have you read it?
Options: Yes, more than 3 years ago / Yes, less than 3 years ago / No

11.2 Could you tell where the instructions can be found?
Options: Yes, I know precisely where to find them / Yes, I know approximately, but it might take a few clicks to find them / Yes, I know, but only at the level that it is in the Pro3-system / No, I do not know where to find them

PART 12

11.3 Free comment: Do you have something else related to risk management or this questionnaire in your mind?

Big thanks for your answers!